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<b>(57) Abstract</b> <p>The isolation and characterization of genes involved in proteolytic processing in species of the genus <i>Pichia</i> is described. The availability of such genes has enabled the generation of strains of <i>Pichia</i> that are deficient in proteolytic activity and useful as hosts for the expression of proteolytically sensitive recombinant products. The isolation and characterization of additional genes from species of the genus <i>Pichia</i> is also described, as well as uses therefor.</p>			

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GENES WHICH INFLUENCE *PICHIA* PROTEOLYTIC ACTIVITY, AND USES THEREFOR

This invention relates to recombinant DNA technology. In a particular aspect, the present invention relates to yeast strains produced employing recombinant techniques, and DNA encoding proteins involved in proteolytic processing, as well as auxotrophic marker proteins. In another aspect, the present invention relates to methods of producing recombinant products, especially recombinant products which are susceptible to proteolytic degradation.

10 **BACKGROUND OF THE INVENTION**

Strains of the genus *Pichia* have been developed as an efficient expression system for the production of recombinant products. Unfortunately, however, some protein products which are desirably produced by recombinant means (e.g., IGF-1, EGF, GRF, and the like) are susceptible to degradation by proteases produced by the host organism. In such cases, even if high levels of the desired product are expressed, reduced product recoveries are sometimes realized due to degradation of the product in the presence of certain of the host strain's proteolytic enzymes. Product recovery is further complicated by the presence of various proteolysis degradation products.

It would be desirable, in view of the excellent performance of the *Pichia*-based expression system for the production of many recombinant products, to reduce or eliminate certain proteolytic activities of *Pichia*. This would reduce the likelihood of degradation of protease-sensitive products when produced in recombinant

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*Pichia* hosts. Reduced likelihood of degradation would result in an enhanced ability to express and recover such products in substantially intact form.

Various techniques can be applied in an effort to 5 reduce or eliminate the problem of proteolytic degradation of recombinantly produced products. For example, one could modify the conditions under which recombinant strains are grown so as to inhibit protease activity. This could be accomplished, for example, by 10 adjusting the pH of the medium sufficiently to inhibit the action of various proteases. This approach, however, may affect the ability of the host organism to express certain recombinant products (as well as the stability of the resulting product, once expressed). Moreover, this 15 approach is limited only to its effect on extracellular proteolysis.

Alternatively, one could attempt to modify or eliminate some or all of the host organism's processing enzymes which are responsible for the proteolytic 20 activity which degrades recombinantly produced, proteolytically sensitive products. Proteolytic processes in eukaryotic organisms are, however, quite complicated and involved. Thus, it is not possible to predict if elimination and/or modification of one or more 25 of the enzyme(s) that are involved in proteolytic processing pathways will have an impact on the viability of the host cells, and/or the stability of the recombinantly produced products.

Some of the proteolytic activities of the yeast 30 *Saccharomyces cerevisiae* have been characterized. Proteinase A, for example, is encoded by the *S. cerevisiae PEP4* gene. Proteinase A is a vacuolar, aspartyl protease capable of self-activation, as well as subsequent activation of additional vacuolar proteases, 35 such as carboxypeptidase Y, and proteinase B. Although

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carboxypeptidase Y appears to be completely inactive prior to proteinase A-mediated proteolytic processing of the enzyme, proteinase B (encoded by the PRB-1 gene of *S. cerevisiae*) reportedly is approximately 50% bioactive in 5 its precursor form, the form that exists prior to proteinase A-mediated processing of the enzyme.

*S. cerevisiae* and filamentous fungi deficient in proteolytic activity have been used for the recombinant expression of heterologous peptides. These organisms, 10 however, differ substantially from the methylotrophic yeast, *Pichia*. There are numerous metabolic and physiological differences between *Saccharomyces*, *Aspergillus*, and *Pichia*, so that the proteolytic processing systems of these various organisms are not 15 necessarily similar. Indeed, very little is presently known regarding the types of proteolytic activities present in *Pichia*.

In addition, unlike *Saccharomyces* or *Aspergillus*, *Pichia* cells used for the recombinant expression of 20 heterologous peptides are typically grown to high cell density, which has been made possible, at least in part, by selection of strains which minimize the occurrence of foaming during the fermentation process. Selection of such cells is accomplished by selecting for cells which 25 produce large amounts of endo- and exo-proteases, which reduce foaming by reducing the size of proteins secreted into the medium. Furthermore, while growth at high cell density the production of heterologous peptides in high yields, growth at high cell density also provides for a 30 relatively high level of vacuolar proteases in the fermentation medium. The high cell density is accompanied by the release of substantial quantities of cellular material into the media, including vacuolar proteases, since ~1% of cells typically undergo lysis 35 during yeast fermentation. Therefore, during the

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production of heterologous peptides in a high cell density process, some of the secreted, heterologous peptides produced by *Pichia* could be subjected to substantial proteolysis.

5 Therefore, it is an object herein, to provide protease deficient strains of *Pichia* and to provide means for generating such strains. It is also an object to use the protease deficient strains for expression of heterologous proteins.

10 **SUMMARY OF THE INVENTION**

In accordance with the present invention, we have isolated and characterized genes involved in proteolytic processes of species of the genus *Pichia*. The availability of such genes provides a means to generate 15 strains of *Pichia* which are deficient in proteolytic activity and which are useful as hosts for the expression of proteolytically sensitive products.

The strains of *Pichia* which have been modified so as to be defective in proteolytic activity, compared to 20 wild-type *Pichia* cells, are excellent hosts for the expression of recombinant constructs encoding proteolytically sensitive products. The advantage of high levels of recombinant product expression using the *Pichia* expression system, coupled with the low level of 25 proteolytic activity in the protease-deficient host cells provided herein, provides a highly efficient expression system for the production of proteolytically sensitive products.

In accordance with another embodiment, a gene that 30 encodes the *Pichia* orotidine-5'-phosphate decarboxylase protein (the *URA3* gene) is provided. The availability of this gene, in combination with strains of *Pichia* which are *Ura*<sup>-</sup>, provides a selection system for use in producing recombinant strains of *Pichia* which are deficient in 35 proteolytic activity. Such *Ura*<sup>-</sup> strains are also useful

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as hosts for transformation with recombinant DNA constructs, which are then used for the recombinant expression of a variety of heterologous products.

**BRIEF DESCRIPTION OF THE FIGURES**

5       Figure 1 is a restriction map of a *Pichia pastoris* gene which influences the carboxypeptidase Y activity of *Pichia*.

Figure 2 is a restriction map of plasmid pEP202.

Figure 3 is a restriction map of plasmid pEP205.

10       Figure 4 is a restriction map of plasmid pEP301.

Figure 5 is a restriction map of plasmid pDR401.

Figure 6 is a restriction map of plasmid pPU201.

Figure 7 is a restriction map of plasmid pPU202.

Figure 8 is a restriction map of plasmid pPU203.

15       Figure 9 is a restriction map of plasmid pPU205.

Figure 10 is a restriction map of plasmid pPU206.

Figure 11 is a restriction map of plasmid pDR421.

15       Figure 12 is a restriction map of the *Pichia pastoris* orotidine-5'-phosphate decarboxylase gene (i.e., the *URA3* gene).

Figure 13 summarizes the steps employed in the construction of pDR601 and pDR602.

Figure 14 is a restriction map of plasmid pDR601.

Figure 15 is a restriction map of plasmid pDR602.

25       Figure 16 is a restriction map of plasmid pDL521.

Figure 17 is a restriction map of a portion of the *Pichia pastoris* proteinase B gene.

Figure 18 is a restriction map of plasmid pDR911.

**DETAILED DESCRIPTION OF THE INVENTION**

30       In accordance with the present invention, there is provided an isolated DNA fragment obtained from a strain of the genus *Pichia* which comprises a gene encoding a protein which, directly or indirectly, influences the proteolytic activity of said strain.

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In accordance with another embodiment of the present invention, there is provided a method of producing modified strain(s) of the genus *Pichia* which are deficient in proteolytic activity, relative to host 5 strain(s) of the same species which are not so modified, said method comprising:

contacting said host strain(s) with a modified form of the above-described gene, wherein said modification renders the gene incapable of producing functional 10 product, or alters the ability of the gene product to influence proteolytic activity, wherein said contacting is carried out under conditions suitable for the site-directed integration of said modified form of the above-described gene into the genome of said host strain(s), 15 wherein said site-directed integration occurs at the specific locus of said gene which encodes said protein which influences proteolytic activity.

In accordance with yet another embodiment of the present invention, there are provided strains of the 20 genus *Pichia* which are deficient in proteolytic activity. Such strains can be produced in a variety of ways, with the above-described method being the presently preferred way of producing such strains.

In accordance with still another embodiment of the 25 present invention, there is provided a method for the expression of proteolytically sensitive recombinant product(s), said method comprising expressing said proteolytically sensitive product(s) in the above-described *Pichia* cells which are deficient in proteolytic 30 activity.

In accordance with a further embodiment of the present invention, there is provided an isolated DNA fragment obtained from a species of the genus *Pichia* which comprises the orotidine-5'-phosphate decarboxylase 35 gene.

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In accordance with a still further embodiment of the present invention, there is provided a yeast cell of the genus *Pichia* as a host capable of being transformed with recombinant DNA material, wherein said host is defective 5 in the orotidine-5'-phosphate decarboxylase gene.

As employed herein, the term "proteolytic activity" refers to any one or more of the enzyme activities displayed by enzymes involved in the proteolytic pathway. Proteolytic activities include proteinase A activity, 10 proteinase B activity, carboxypeptidase Y activity, carboxypeptidase S activity, aminopeptidase C activity, dipeptidyl aminopeptidase activity, proteinase D activity, proteinase E activity, and the like.

As used herein, a gene encoding a protein which, 15 directly or indirectly, influences the proteolytic activity of a yeast strain, includes genes that encode proteinases or that encode proteins that act on proteinases. As used herein, a protein that acts on a protein refer to proteins that alter or modulate the 20 activity of a proteinase. Thus, for example, a protein that directly influences proteolytic activity is a protein that encodes a proteinase, and a protein that indirectly influences proteolytic activity is a protein that activates or increases the activity of a protein by 25 proteolytic processing. *Saccharomyces cerevisiae* proteinase is an example of a protein that directly and indirectly influences the proteolytic activity of *Saccharomyces cerevisiae*.

In accordance with one embodiment of the present 30 invention, the *Pichia* gene that encodes a protein which, directly or indirectly, influences at least the carboxypeptidase Y activity of strains of the genus *Pichia* has been identified and isolated from a species of the genus *Pichia*. This gene is referred to herein, for 35 convenience, as the *Pichia PEP4* gene, based on the

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existence of some similarity between this gene and the *S. cerevisiae* *PEP4* gene. It should be recognized, however, that the nucleotide sequences of the *Pichia* gene and the *Saccharomyces* gene differ substantially. The *Pichia* *PEP4* gene is characterized by the restriction map set forth in Figure 1 of the drawings. A fragment containing sequences encoding this gene can be readily obtained for easy handling from a variety of sources. One such source is the approximately 10.6 kbp EcoRI fragment of plasmid 5 *PEP202* (see Figure 2), or alternatively, the approximately 2.7 kbp EcoRI-SacI fragment of plasmid 10 *PEP301* (see Figure 4).

DNA encoding the proteinase A gene is also provided. The proteinase A gene of the present invention can be 15 further characterized by reference to the amino acid sequence set forth in Sequence ID No. 2. DNA having any nucleic acid sequence which encodes substantially the same amino acid sequence as set forth in Sequence ID No. 2 or that has sufficient homology to be useful for 20 disruption of homologous genes can be employed in the practice of the present invention. An exemplary nucleic acid sequence which encodes the above-described amino acid sequence is set forth in Sequence ID No. 1.

The *Pichia* gene that encodes a protein which, 25 directly or indirectly, influences the proteolytic activity of strains of the genus *Pichia* can be modified in a variety of ways, so as to render the gene incapable of producing functional product, or so as to alter the ability of the gene product to influence the proteolytic 30 activity of said *Pichia* strain(s). Those of skill in the art recognize that there are many methods for the modification of the above-described gene. For example, the coding sequence can be mutated to modify the amino acid sequence of the protein encoded by the gene. 35 Alternatively, various portions of the coding sequence

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can be deleted from the gene. The deletion need only be sufficient to render the expressed product (if it is still capable of being expressed) non-functional. Thus, a deletion of even one nucleotide, by throwing the 5 remaining coding sequence out of reading frame, can render a product, if still capable of expression, non-functional. Of course, larger deletions can result in a complete lack of expression of product, or can cause a substantially modified product to be expressed, and such 10 a product is likely to have very different proteolytic properties, if any, relative to product produced by intact gene. As yet another alternative, additional sequences can be inserted into the coding sequence to disrupt the reading frame of the gene of interest, which 15 would cause a dramatically altered product to be expressed, or a complete lack of expression of the product.

A particularly convenient method for the modification of the *Pichia* gene that encodes a protein 20 which, directly or indirectly, influences the proteolytic activity of strains of the genus *Pichia* is to insert an auxotrophic marker gene into said *Pichia* gene, thereby disrupting the *Pichia* gene. Such auxotrophic marker genes can be selected from the *Pichia* or *Saccharomyces* 25 *HIS4* gene, the *Pichia* or *Saccharomyces ARG4* genes, the *Pichia* or *Saccharomyces URA3* genes, and the like.

Strains of *Pichia* deficient in proteolytic activity can be prepared in a variety of ways. The presently preferred method involves modifying, in a suitable host, 30 genes of the present invention (which genes, in their unmodified form, encode a product which, directly or indirectly, affects the proteolytic activity of strains of the genus *Pichia*). Alternatively, host strains can be subjected to random (i.e., non-selective) mutagenesis,

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then screened to select for mutants which are deficient in proteolytic activity.

When proteolytically deficient strains are produced by modifying the gene of the invention in a host, such 5 modifying is carried out, for example, by introducing a modified gene under transformation conditions suitable for the site-directed integration of the modified gene into the genome of the host at the specific locus of such gene which encodes a protein which influences proteolytic 10 activity (i.e., the target gene). Integration will replace or alter the host's endogenous gene. A convenient means to introduce the modified gene into the target locus of a yeast host is to include the modified gene in a linear DNA fragment having ends homologous to 15 two separate portions of the intact gene within the host. This will direct, upon transformation, homologous recombination occur at the specific locus of the gene whose expression product influences proteolytic activity.

When *Pichia* strains deficient in proteolytic 20 activity are prepared by the preferred method described above (i.e., by introducing a modified gene of the invention into a suitable host by site-directed integration at the specific locus of the gene whose expression product influences proteolytic activity, 25 thereby replacing all or a portion of the endogenous gene with all or a portion of the modified gene), the endogenous gene is said to be disrupted.

As used herein, the term gene "disruption" refers to any manipulation of the target locus that ultimately 30 results in the presence of a gene that does not yield a functional product, or that yields a product with altered function. Disruption can, therefore, result from the presence of added sequence (e.g., by the introduction of auxotrophic marker, or by the introduction of any 35 sequence which causes a shift in the reading frame), the

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loss of nucleotides from the target gene (e.g., by deletion), or other mutations of the target gene. For the preferred method of preparing *Pichia* strains deficient in proteolytic activity, gene disruption is

5 achieved by gene addition, gene replacement, or a combination of addition and replacement referred to herein as "pop-in-pop-out". In gene replacement, the endogenous target gene is physically removed from the target locus, and replaced with the modified gene. This

10 is accomplished by transforming the host with a linear fragment having ends which are homologous to the 5' and 3' ends of the target gene, respectively. Gene addition involves adding the transforming DNA to the endogenous target gene. Depending on the manner in which the

15 modified gene of the transforming DNA was altered, gene addition can result in the presence of either two non-functional copies of the target gene, or one functional and one non-functional copy of the target gene. Each of the two copies consists of a portion of the endogenous

20 gene, and a portion of the transforming DNA. If a functional copy of the target gene remains after gene addition, it can then be removed by homologous recombination between the two copies of the target gene. The combination process of gene addition followed by

25 homologous recombination constitutes the pop-in-pop-out process.

Methods of transforming yeast of the genus *Pichia*, as well as methods applicable for culturing such yeast cells, are known generally in the art. Constructs

30 containing the above-described modified gene are transformed into *Pichia* cells either by the spheroplast technique, described by Cregg et al., in Mol. Cell. Biol. 5:3376 (1985) and U.S. 4,879,231, or by the whole-cell lithium chloride yeast transformation system [Ito et al.,

35 Agric. Biol. Chem. 48:341 (1984)], with modification

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necessary for adaptation to *Pichia* [See European Patent Application No. 312,934; also available as U.S. Pat. No. 4,929,535]. The whole-cell lithium chloride method is frequently more convenient in that it does not require 5 the generation and maintenance of spheroplasts. For the purpose of the present invention, the spheroplast method is preferred because the spheroplast method is generally a more efficient means of transformation.

Those of skill in the art recognize that host *Pichia* 10 strains for transformation with the above-described modified gene can be wild-type *Pichia* cells, which upon transformation with a defective gene from the proteolytic pathway, could be screened for reduced proteolytic activity. The host strains employed can have one or more 15 defects therein, to assist in the identification and selection of desired transformants.

Preferred hosts employed for transformation with a modified form of the gene which encodes a protein which, directly or indirectly, influences the proteolytic 20 activity of strains of *Pichia*, is a strain which is defective in at least one auxotrophic marker gene. The use of such host organisms is preferred because simultaneous transformation of such a host with the modified form of the invention gene and an auxotrophic 25 marker gene enables rapid selection of strains which have incorporated the transforming DNA, and thus, should have a disrupted form of the gene which encodes a protein which directly or indirectly influences the proteolytic activity of the host.

30 Exemplary auxotrophic marker genes useful in the practice of the present invention (i.e., marker genes that are defective in the preferred host strains employed herein) include the histidinol dehydrogenase gene, the argininosuccinate lyase gene, or the 35 orotidine-5'-phosphate decarboxylase gene, and the like.

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When employing such host strains in the transformation of *Pichia*, the above-described modified gene, included on a linear DNA fragment, is preferably associated with an intact form of the auxotrophic marker gene for which the 5 host strain is defective, e.g., the auxotrophic marker gene either is contained within the modified gene, or is located 5' or 3' of the modified gene on the transforming linear DNA fragment. Exemplary host strains contemplated for use in the practice of the present 10 invention include the *HIS4*-defective *Pichia* strain, GS115 (ATCC 20864), the *ARG4*-defective *Pichia* strain, GS190, the *HIS4/URA3*-defective *Pichia* strain, GS4-2, the *HIS4/ARG4*-defective *Pichia* strain PPF1 (NRRL Y-18017; see 15 U.S. 4,812,405), and the like. An exemplary fragment of DNA which contains the above-described modified gene having inserted therein a functional gene encoding histidinol dehydrogenase can be obtained from the approximately 5.3 kbp SacI-EcoRI fragment of plasmid pDR401. Another exemplary fragment of DNA which contains 20 a modified form of the above-described gene (located 5' of a functional gene encoding orotidine-5'-phosphate decarboxylase) can be obtained from the approximately 5.0 kbp BglII fragment of plasmid pDR421.

A particularly advantageous application of the 25 *Pichia* strains that are deficient in proteolytic activity is for the expression of proteolytically sensitive recombinant products, such as, for example, epidermal growth factor (EGF), growth hormone releasing factor (GRF), insulin-like growth factor-1 (IGF-1), and the 30 like. When expressed in recombinant *Pichia* strains, which are deficient in proteolytic activity, the resulting recombinant product is subjected to a reduced level of proteolytic activity, due to modifications in the proteolysis apparatus of the host organism.

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Proteolytically deficient *Pichia* expression systems for the production of proteolytically sensitive products can be generated in a variety of ways. For example, *Pichia* host strains can be rendered proteolytically 5 deficient, as described hereinabove, and then further transformed with DNA encoding a heterologous protein of interest (especially a proteolytically sensitive protein). Alternatively, a recombinant *Pichia* strain already bearing DNA encoding a heterologous protein of 10 interest can thereafter be rendered proteolytically deficient, for example, as described hereinabove. As yet another alternative, a *Pichia* strain could be co-transformed with the above described modified gene and a DNA encoding a heterologous, proteolytically sensitive 15 protein of interest.

The use of strains of the genus *Pichia* as host strains in the recombinant expression of peptide products has previously been described in great detail. The presently preferred yeast species for use in the 20 practice of the present invention is *Pichia pastoris*, a known industrial yeast strain that is capable of efficiently utilizing methanol as the sole carbon and energy source.

There are a number of methanol-responsive genes in 25 methylotrophic yeast, the expression of each being controlled by methanol-responsive regulatory regions (also referred to as promoters). Any of such methanol-responsive promoters are suitable for use in the practice of the present invention. Examples of specific 30 regulatory regions include the promoter for the primary alcohol oxidase gene from *Pichia pastoris* AOX1, the promoter for the secondary alcohol oxidase gene from *P. pastoris* AOX2 (*P. pastoris* is known to contain two functional alcohol oxidase genes: alcohol oxidase I 35 (AOX1) and alcohol oxidase II (AOX2); the coding portions

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of the two AOX genes are closely homologous at both the DNA and the predicted amino acid sequence levels and share common restriction sites; the proteins expressed from the two genes have similar enzymatic properties but 5 the promoter of the AOX1 gene is more efficient and gene products are frequently more highly expressed therefrom), the promoter for the dihydroxyacetone synthase gene from *P. pastoris* (*DAS*), the promoter for the P40 gene from *P. pastoris*, the promoter for the catalase gene from *P. pastoris*, the promoter for the formaldehyde dehydrogenase 10 gene from *P. pastoris*, the promoter for the formate dehydrogenase gene from *P. pastoris*, and the like.

The presently preferred promoter region for regulating expression of a gene encoding a 15 proteolytically sensitive product, in *P. pastoris* hosts, is the promoter of the methanol-regulated primary alcohol oxidase gene of *P. pastoris*. The AOX1 gene, including its promoter, has been isolated and thoroughly characterized; see Ellis et al., Mol. Cell. Biol. 5: 1111 20 (1985) and U.S. Patent No. 4,855,231.

The presently preferred expression cassette used in transforming *Pichia* cells for the generation of recombinant protein-expressing strains comprises, in the reading frame direction of transcription, the following 25 DNA sequences:

- (i) a promoter region of a methanol-responsive gene of a methylotrophic yeast,
- (ii) a DNA sequence encoding a polypeptide consisting essentially of:
  - (a) an optional secretion signal sequence, and
  - (b) a heterologous protein of interest; and
- (iii) a transcription terminator functional in a methylotrophic yeast;

wherein said DNA sequences are operationally associated 30 with one another for transcription of the sequences

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encoding said polypeptide. DNA sequences encoding a secretion signal sequence which are optionally contained in expression vectors used in the practice of the present invention include the DNA encoding the native secretion 5 signal sequence associated with the proteolytically sensitive product, the DNA encoding the *S. cerevisiae*  $\alpha$ -mating factor ( $\alpha$ MF) leader sequence, (including a DNA sequence encoding the processing site, lys-arg), and signal sequences that function as such in methylotrophic 10 yeast cells, such as the bovine lysozyme C signal sequence.

The transcription terminator functional in a methylotrophic yeast used in accordance with the present invention has either (a) a subsegment which provides a 15 polyadenylation signal and polyadenylation site in the transcript, and/or (b) a subsegment which provides a transcription termination signal for transcription from the promoter used in the expression cassette. The term "expression cassette" as used herein, and throughout the 20 specification and claims, refers to a DNA sequence which includes sequences functional for the expression process. The entire transcription terminator is taken from a protein-encoding gene, which may be the same or different from the gene which is the source of the promoter.

25 In the DNA constructs of the present invention, used to transform hosts for recombinant expression of proteolytically sensitive products, the segments of the expression cassette(s) are said to be "operationally associated" with one another. The DNA sequence encoding 30 proteolytically sensitive products is positioned and oriented functionally with respect to the promoter, the secretion signal sequence, if employed, and the transcription terminator. Thus, the polypeptide-encoding segment is transcribed, under regulation of the promoter 35 region, into a transcript capable of providing, upon

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translation, the desired polypeptide. Appropriate reading frame positioning and orientation of the various segments of the expression cassette are within the knowledge of persons of ordinary skill in the art; 5 further details are given in the Examples.

For the practice of the present invention it is preferred that hosts for the recombinant expression of proteolytically sensitive products be transformed with multiple copies of the above-described expression 10 cassettes contained on one DNA fragment, preferably in a head-to-tail orientation.

In addition, when DNA constructs according to the invention are used to transform hosts for the recombinant expression of proteolytically sensitive products by 15 site-directed integration, the expression cassette-containing construct is a linear DNA fragment that is directed to the desired locus of the host to effect integration of the DNA fragment therein. One-step gene integrations are usually successful if the DNA to be 20 introduced has as little as 0.2 kb homology with the fragment locus of the target gene; it is however, preferable to maximize the degree of homology for efficiency.

The DNA constructs used according to the invention 25 to transform hosts for the recombinant expression of proteolytically sensitive products optionally further comprise a selectable marker gene, in addition to one or more expression cassettes. For this purpose, any selectable marker gene functional in methylotrophic yeast 30 may be employed, i.e., any gene which confers a phenotype upon methylotrophic yeast cells, thereby allowing them to be identified and selectively grown from among a vast majority of untransformed cells. Suitable selectable marker genes include, for example, selectable marker 35 systems composed of an auxotrophic mutant *P. pastoris*

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host strain and a wild-type biosynthetic gene which complements the host's defect. For transformation of *HIS4*<sup>-</sup> *P. pastoris* strains, for example, the *S. cerevisiae* or *P. pastoris* *HIS4* gene may be employed, or for 5 transformation of *ARG4*<sup>-</sup> mutant *P. pastoris* strains, the *S. cerevisiae* *ARG4* gene or the *P. pastoris* *ARG4* gene may be employed, or for transformation of *URA3*<sup>-</sup> mutant *P. pastoris* strains, the *S. cerevisiae* *URA3* gene or the *P. pastoris* *URA3* gene may be employed.

10 In addition, DNA constructs used to transform hosts for the recombinant expression of proteolytically sensitive products according to this aspect of the invention optionally further comprise selectable marker genes which are functional in bacteria. Thus, any gene 15 can be used which confers a phenotype on bacteria that allows transformed bacterial cells to be identified and selectively grown from among a vast majority of untransformed cells. This additional selectable marker enables DNA of the invention to be transformed into 20 bacteria such as *E. coli* for amplification. Suitable selectable marker genes include the ampicillin resistance gene (Amp<sup>r</sup>), tetracycline resistance gene (Tc<sup>r</sup>), and the like.

When it is contemplated to pass DNA of the invention 25 through bacterial cells, it is desirable to include in the DNA construct a bacterial origin of replication, to ensure the maintenance of the invention DNA from generation to generation of the bacteria. Exemplary bacterial origins of replication include the f1-ori, 30 colisin, col E1, and the like.

The term "expression vector", as employed herein, is intended to include vectors capable of expressing DNA sequences contained therein, where such sequences are in operational association with other sequences capable of 35 effecting their expression, i.e., promoter sequences. In

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general, expression vectors usually used in recombinant DNA technology are often in the form of "plasmids", i.e., circular, double-stranded DNA loops, which in their vector form are not bound to the chromosome. In the 5 present specification the terms "vector" and "plasmid" are used interchangeably. However, the invention is intended to include other forms of expression vectors as well, which function equivalently.

Methods of transforming yeast of the genus *Pichia*, 10 as well as methods applicable for culturing such yeast cells, are known generally in the art.

According to the invention, constructs containing the above-described modified gene and/or expression cassettes encoding the production of heterologous, 15 proteolytically sensitive products are transformed into *Pichia* cells either by the spheroplast technique, or by the whole-cell lithium chloride yeast transformation system, as described above.

Transformed strains, which are of the desired 20 phenotype and genotype, are grown in fermentors in either batch or continuous mode. For the large-scale production of recombinant DNA-based products in methylotrophic yeast, a three-stage, high cell-density fermentation system is the presently preferred fermentation protocol 25 employed. In the first, or growth stage, expression hosts are cultured in defined minimal medium with an excess of a non-inducing carbon source (e.g., glycerol). When grown on such carbon sources, heterologous gene expression is completely repressed, which allows the 30 generation of cell mass in the absence of heterologous protein expression. It is presently preferred, during this growth stage, that the pH of the medium be maintained at about 5, because the *P. pastoris* cells generally prefer a pH of about 5 for optimal growth. 35 Next, a short period of non-inducing carbon source

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limitation growth is allowed to further increase cell mass and derepress the methanol-responsive promoter. The pH of the medium during this limitation growth period is maintained at an appropriate pH value (the actual pH 5 employed is a function of the particular host strain used for expression and the specific product being expressed).

Subsequent to the period of growth under limiting conditions, methanol is added in the fermentor either on a continuous basis, with concurrent removal of product 10 via the broth; or on a batch-wise basis wherein methanol is added at such a rate that the methanol content of the broth is maintained at a low level (referred to herein as "methanol excess fed-batch mode"). The addition of methanol induces the expression of the gene driven by a 15 methanol-responsive promoter. This third stage is referred to as the production stage, because it is at this stage that the majority of the recombinant product is expressed. The pH of the medium during the production stage is maintained at an appropriate pH value (the 20 actual pH employed is a function of the particular host strain used for expression and the specific product being expressed).

The term "culture" means a propagation of cells in a medium conducive to their growth, and all 25 sub-cultures thereof. The term "subculture" refers to a culture of cells grown from cells of another culture (source culture), or any subculture of the source culture, regardless of the number of subculturing steps that have been performed between the subculture of 30 interest and the source culture.

According to a preferred embodiment of the present invention, the heterologous protein expression system used for the production of proteolytically sensitive products utilizes the promoter derived from the methanol-regulated *AOX1* gene of *P. pastoris*, which is very 35

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efficient and tightly regulated. This gene can be the source of the transcription terminator as well. The presently preferred expression cassette comprises, operationally associated with one another, the *P. pastoris* AOX1 promoter, optional DNA encoding a secretion signal sequence, a DNA sequence encoding a proteolytically sensitive product (e.g., mature IGF-1, EGF, GRF, and the like), and a transcription terminator derived from the *P. pastoris* AOX1 gene. Preferably, two or more of such expression cassettes are contained on one DNA fragment, in head-to-tail orientation, to yield multiple expression cassettes on a single contiguous DNA fragment.

The presently preferred host cells to be transformed with multiple expression cassettes are *P. pastoris* cells having at least one mutation that can be complemented with a marker gene present on a transforming DNA fragment. Preferably *HIS4*<sup>-</sup> (GS115) or *ARG4*<sup>-</sup> (GS190) single auxotrophic mutant *P. pastoris* strains are employed, or *HIS4*<sup>-</sup>/*URA3*<sup>-</sup> (GS4-2) or *HIS4*<sup>-</sup>/*ARG4*<sup>-</sup> (PPF1) double auxotrophic mutant *P. pastoris* strains are employed.

The fragment containing one or more expression cassette(s) is inserted into a plasmid containing a marker gene complementing a metabolic defect in the host, and optionally containing additional sequences such as bacterial marker genes, yeast DNA sequences which direct vector integration, and the like.

In accordance with a specific embodiment of the present invention, there is provided an isolated DNA fragment obtained from a species of the genus *Pichia* which comprises the orotidine-5'-phosphate decarboxylase gene. The orotidine-5'-phosphate decarboxylase gene is frequently referred to as *URA3*. It can be used, for example, to complement *URA3*-deficient strains. Another use for the novel gene is the ability to target DNA into

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a specific locus of the *Pichia* genome (i.e., into the *URA3* locus). This novel gene can be characterized by reference to the restriction map shown in Figure 12. Alternatively, this novel gene can be characterized as 5 encoding a protein having substantially the same amino acid sequence as set forth in Sequence ID No. 4. While those of skill in the art recognize that the above-referenced amino acid sequence can be encoded by a variety of nucleotide sequences, a presently preferred 10 nucleotide sequence encoding the above-referenced amino acid sequence is substantially the same as that set forth in Sequence ID No. 3.

In accordance with another specific embodiment of the present invention, there are provided yeast cells of 15 the genus *Pichia* as a host capable of being transformed with recombinant DNA material, wherein the host is defective in the orotidine-5'-phosphate decarboxylase gene. Host strains defective in the *URA3* gene can be used for transformation with DNA containing an intact 20 form of the *URA3* gene, thereby enabling a ready determination of whether the desired transformation event has occurred (by return of successfully transformed cells to uracil prototrophy).

The combination of *URA3* *Pichia* strains and 25 the *Pichia* orotidine-5'-phosphate decarboxylase marker gene provides a particularly useful selection system for use in producing recombinant strains of *Pichia* deficient in proteolytic activity. Such a selection system is referred to herein as a "bidirectional 30 selection process". This selection system for the generation of *Pichia* strains which are deficient in proteolytic activity uses a "pop-in-pop-out" gene disruption technology in which a DNA fragment containing a defective gene is added to the genome 35 of a host organism, with subsequent removal of

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portions of the DNA fragment and endogenous sequences from the host through homologous recombination between the endogenous target gene sequence and the integrated vector sequence. Initially, transformants are selected  
5 for incorporation of the disruption vector which contains a marker gene such as *URA3* (i.e., the "pop-in" step). Next, the selected transformants must be screened to identify strains in which a recombination event between endogenous gene sequences and integrated vector sequences  
10 has occurred and has thereby excised portions of the vector, including the marker gene, and endogenous sequences of the host (i.e., the "pop-out" step). A double selection system based on the *URA3* gene and *URA3*-hosts provides for the sequential identification of the  
15 desired strains.

This type of gene disruption is typically conducted in *Ura*<sup>-</sup> strains, which can be identified by resistance to 5-fluoro-orotic acid (5-FOA). Disruption vectors contain a defective copy of the target gene to be disrupted and a  
20 functional *URA3* gene. Integration of the disruption vector into the genome of the *Ura*<sup>-</sup> host cells generates *Ura*<sup>+</sup> transformants containing one functional target gene and one non-functional (i.e., defective) target gene. *Ura*<sup>+</sup> transformants are easily identified by their ability  
25 to grow in the absence of uracil.

In order to isolate strains in which a recombination event has resulted in the elimination of the functional target gene, leaving only a defective gene, the *Ura*<sup>+</sup> transformants are screened for restoration of 5-FOA  
30 resistance resulting from the loss ("pop-out") of the *URA3* gene which accompanies recombination. The regeneration of the *URA3* genotype enables repetition of the "pop-in-pop-out" process for the subsequent disruption of other genes in the genome. To use this  
35 selection system for the generation of *Pichia* strains

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which are deficient in proteolytic activity, a *URA3*<sup>-</sup> host is transformed with a DNA construct containing a modified form of a gene encoding a protein involved in the *Pichia* proteolytic pathway, and the *URA3* gene. Site-directed 5 integration of the transforming DNA by gene addition (i.e., "pop-in") yields one functional and one non-functional gene at the locus of the gene which directly or indirectly influences proteolytic activity, as well as an intact *URA3* gene. Strains which incorporate the *URA3* 10 gene are identified by positive selection (using techniques well known to those of skill in the art, e.g., by growing the strains on minimal media lacking uracil and selecting those strains capable of growth on such media). The configuration of the functional, non-functional and *URA3* genes at the locus of the gene which encodes a protein which influences proteolytic activity 15 enables recombination to occur between the functional and non-functional genes, resulting in the loss of one of these genes and the *URA3* gene (i.e., "pop-out").

20 Thereafter, it is possible to positively select for strains lacking a functional *URA3* gene by plating cells on medium containing a non-toxic analog of a uracil pathway intermediate, 5-fluoro-orotic acid (5-FOA), which, when metabolized by *URA3*<sup>+</sup> strains, produces a 25 compound toxic to the cells. Because *URA3*<sup>-</sup> strains blocked at a specific point in the uracil pathway do not metabolize 5-FOA, they are not subjected to its toxic effects, and can thus be referred to as "5-FOA resistant". In contrast, *URA3*<sup>+</sup> strains metabolize 5-FOA 30 to produce a toxic compound which will prevent growth of the *URA3*<sup>+</sup> cells. The resulting *URA3*<sup>-</sup> cells that also lack the functional target gene are deficient in proteolytic activity. Because the *URA3*<sup>-</sup> phenotype is restored, the resulting cells can be transformed again using the *URA3* 35 gene as a selectable marker.

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The ability to positively select strains lacking a functional *URA3* gene employing a toxic analog of a uracil pathway intermediate allows the use of this very convenient "pop-out" method for imparting multiple 5 phenotypic changes in *Pichia* hosts.

*URA3*<sup>-</sup> *Pichia* strains which are also deficient in proteolytic activity, relative to the proteolytic activity present in wild-type strains of the same species, are particularly useful for transformation with 10 expression vectors which contain an intact form of the *URA3* gene, and a gene encoding a proteolytically sensitive product (either as part of the same vector, or as a second vector which is transformed into the host). Those transformants which return to uracil prototrophy 15 (which can be readily determined by simple screening procedures) should have incorporated therein the gene encoding a proteolytically sensitive product, and thus would be directly applicable to product expression.

The invention will now be described in greater 20 detail by reference to the following non-limiting examples.

#### EXAMPLES

##### EXAMPLE I: ISOLATION OF THE *P. PASTORIS* *PEP4* GENE

The *P. pastoris* *PEP4* gene was identified in a bacteriophage lambda-based EMBL3 *P. pastoris* genomic DNA 5 library by its ability to hybridize with a radiolabeled fragment of the homologous *Saccharomyces cerevisiae* *PEP4* gene. The *P. pastoris* *PEP4* gene was cloned by isolating positive plaques containing the hybridizing recombinant phage DNA.

10       A. Construction of a *P. pastoris* EMBL3 Genomic DNA Library

Bacteriophage  $\lambda$  was used as a vehicle for cloning the *P. pastoris* *PEP4* gene. Fragments of a partial *Sau3A* digest of *P. pastoris* genomic DNA were inserted into the 15 bacteriophage  $\lambda$  vector EMBL3 [Frischauf, A.-M. et al.

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(1983). J. Mol. Biol. 170:827], which contains elements of the bacteriophage  $\lambda$  genome essential for propagation of the recombinant DNA in bacterial hosts. The *P. pastoris* DNA-containing EMBL3 vectors were packaged in

5 *vitro* into infectious virions to yield a bacteriophage  $\lambda$  *P. pastoris* genomic DNA library. Amplification of the library was achieved by propagation of the recombinant DNA in *Escherichia coli* host cells that had been infected with the recombinant virus.

10 *Pichia pastoris* genomic DNA (from strain NRRL Y-11430, from the Northern Regional Research Center, Peoria, IL) isolated using a glass rod swirl technique [Cregg et al. Mol. Cell. Biol. 5:3376-3385 (1985)] was digested with Sau3A at an effective concentration of 0.1

15  $\mu$ / $\mu$ g in 7, 14, 21 and 28 minute incubations conducted at 37°C. An aliquot from each incubation mixture was electrophoretically separated on a 1% agarose gel to determine the sizes of the digested DNA fragments. Digests incubated for 7 and 14 minutes appeared to

20 consist primarily of 9-23 kb fragments. These digests were pooled and ligated to EMBL3 vector arms, prepared as described below.

EMBL3 vector arms were prepared by double digestion of the vector (obtained from EMBL3 Cloning Kit, 25 Stratagene Cloning Systems, San Diego, CA; catalog #241211) with BamHI and EcoRI. The small BamHI/EcoRI linker that separates the arms from the stuffer fragment was removed from the digest by selective precipitation with ethanol. Ligation of the Sau3A-digested *Pichia* 30 genomic DNA (0.5  $\mu$ g) to 1  $\mu$ g of EMBL3 pre-digested arms was accomplished by incubation of the 5- $\mu$ l reaction mixture at 4°C for two days.

The recombinant bacteriophage  $\lambda$  DNA prepared by ligation of *P. pastoris* genomic DNA fragments and EMBL3 35 vector arms was packaged *in vitro* using commercial

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packaging extracts (Stratagene EMBL3 Cloning Kit). The EMBL3-based *P. pastoris* genomic library was amplified by plating the recombinant phage along with the *E. coli* lysogenic host strain P2 392 (provided in Stratagene 5 EMBL3 Cloning Kit) which contains prophage P2. Wild-type bacteriophage do not grow in *E. coli* strain P2 392. Recombinant EMBL3-based bacteriophage, which lack two of the wild-type genes that confer P2 sensitivity, are able to grow well in this P2-containing *E. coli* strain. The 10 use of *E. coli* P2 392 as the host strain in the amplification ensured that only recombinant phage would be reproduced in the bacterial host.

All of the plates encompassing the EMBL3-based *P. pastoris* genomic DNA library were overlayed with SM 15 buffer (5.8 g NaCl, 2g MgSO<sub>4</sub>·H<sub>2</sub>O, 50 ml 1M Tris·HCl, pH 7.5, and 5 ml 2% gelatin per liter). After five hours, the supernatants were collected and pooled, and the titer and genome equivalents were calculated according to the manufacturer's instructions. The library contained 20 approximately 10 genome equivalents, and its titer was 6 X 10<sup>11</sup> plaque-forming units/ml (pfu/ml).

**B. Screening of the EMBL3 *P. pastoris* Genomic DNA Library Using the *S. cerevisiae* PEP4 Gene as a Probe**

In order to adequately screen the *Pichia* genome for 25 the *PEP4* gene, 50,000 recombinant phage and the *E. coli* lysogenic host strain LE 392 (provided in Stratagene EMBL3 Cloning Kit) were plated onto four large 150-mm plates. After 6-7 hours of growth, the plates were chilled to 4°C. Each plate was marked and duplicate 30 plaque lifts of each plate were prepared by placing nitrocellulose onto each plate. The filters were denatured, neutralized, baked and probed with the *S. cerevisiae* *PEP4* gene [a gel-purified, <sup>32</sup>P-labeled 4.0 kb fragment of *S. cerevisiae* DNA containing the *S. 35 cerevisiae* *PEP4* gene obtained from the laboratory of Thomas Stevens, University of Oregon, Eugene, Oregon; see

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Rothman et al., Proc. Natl. Acad. Sci. USA 83: 3248-3252 (1986)]. Hybridization was conducted at 37°C in a solution containing 30% formamide, 6 X SSC, 5 X Denhardt's solution, 20 mM Tris-HCl, pH 8.0, 1 mM 5 EDTA, 0.1% SDS and 100 µg/ml salmon sperm DNA. After hybridization, the filters were washed three times at room temperature using 2 X SSC and 0.1% SDS. Following these initial washes, the filters were then washed twice at 55°C using 2 X SSC and 0.1% SDS.

10 Fifteen positive plaques containing DNA that hybridized to the fragment of the *S. cerevisiae PEP4* gene were identified in duplicate from autoradiograms of the filters. The area around each of the 15 positive plaques was isolated and placed in SM buffer. Six of the 15 isolates were plated at dilutions of  $10^{-5}$  and  $10^{-7}$  with *E. coli* strain LE 392 onto smaller 100-mm plates. Single plaque lifts of each plate were probed with the *S. cerevisiae PEP4* gene fragment under the same hybridization and wash conditions used in the first 15 plaque screening. In this second round of screening, 12 positive plaques were detected on the autoradiogram. Nine of these single plaques were isolated and placed in SM buffer. Each of these nine plaques was plated at dilutions of  $10^{-5}$  and  $10^{-7}$  with *E. coli* strain LE 392 onto 20 small 100-mm plates. Again, single plaque lifts of each plate were probed with the *S. cerevisiae PEP4* gene fragment under the same hybridization and wash conditions used in the first two screenings. Each plate contained approximately 10-20 plaques distributed evenly across the 25 plate. Autoradiograms of the filters revealed that every 30 plaque on each plate hybridized to the *PEP4* probe.

35 Five separate plaques from different plates were isolated and placed in SM buffer. DNA from large-scale cultures of three of these isolates, designated 4721, 5111 and 5131, respectively, was prepared using the

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induction method of bacteriophage isolation [Maniatis, T., Fritsch, E.F. and Sambrook, J. Molecular Cloning, A Laboratory Manual. Cold Spring Harbor Laboratory Press, Cold Spring Harbor, New York, USA (1982)] in order to

5 identify, characterize and subclone the *PEP4* gene contained in the recombinant phage.

C. Characterization of the Insert in Isolates of the EMBL3 *P. pastoris* Genomic DNA Library that Hybridized to the *S. cerevisiae* *PEP4* Gene

10 Recombinant phage DNA prepared from the three isolates, referred to above, from the EMBL3 *Pichia* genomic DNA library (4721, 5111 and 5131), were digested with various restriction endonucleases, separated on a 0.8% agarose gel and visualized by ethidium bromide staining. In addition, 1  $\mu$ l aliquots of these digests were separated on a second agarose gel which was blotted onto nitrocellulose and probed with the radiolabeled *S. cerevisiae* *PEP4* gene fragment. Hybridization was conducted at 37°C in a solution containing 30% formamide,

15 6 X SSC, 5 X Denhardt's solution, 20 mM Tris-HCl, pH 8.0, 1 mM EDTA, 0.1% SDS and 100  $\mu$ g/ml salmon sperm DNA. The filter was then washed in three 5-minute washes at room temperature with 2 X SSC and 0.1% SDS followed by two 5-minute washes at 55°C with 2 X SSC and 0.1% SDS.

20

25 Identical digests of DNA from two of the clones, 5111 and 5131, yielded the same pattern of restriction enzyme fragments, as determined by ethidium bromide staining, whereas the same digest of DNA from the third clone, 4721, yielded a different fragment pattern.

30 Analysis of the restriction enzyme fragments of DNA from each clone by Southern blot hybridization to the *S. cerevisiae* *PEP4* gene fragment revealed that the two classes of clones both contained a series of hybridizing fragments of the same size indicating that the two

35 classes of clones had a common overlapping DNA sequence that hybridized with the probe.

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**D. Subcloning and Characterization of the Cloned *P. pastoris* PEP4 Gene**

As determined by Southern blot hybridization of EcoRI-digested *P. pastoris* genomic DNA using the homologous *S. cerevisiae* *PEP4* gene as a probe, the *P. pastoris* *PEP4* gene is contained within a 10.6 kb EcoRI fragment of the *P. pastoris* genome. Southern blot hybridization of EcoRI-digested DNA of clone 4721, as described in Example 1C, revealed that it contained a 10.6 kb fragment that hybridized to the *S. cerevisiae* *PEP4* gene. To facilitate manipulation of the cloned *P. pastoris* *PEP4* gene, *P. pastoris* genomic DNA contained on an EcoRI fragment of DNA from isolate 4721 was subcloned into pUC19. Clone 4721 (25 µg) was digested 5 with EcoRI (60 units) in a total volume of 300 µl. The digested DNA was separated on a 0.65% agarose gel, and the 10.6 kb EcoRI fragment was isolated with DE81 paper. The purified fragment was washed from the paper with 400 µl of 1 M NaCl and extracted with phenol/chloroform. The 10. The DNA was then precipitated with ethanol and resuspended in water to a total volume of 10 µl. Approximately 50 ng of the 10.6 kb fragment were ligated with an equal amount of pUC19 which had been cut with EcoRI and dephosphorylated. The ligation mixture was used to transform *E. coli* strain 20 MC1061. Ampicillin-resistant colonies were selected and screened by analysis of restriction enzyme digests of colony DNA for the presence of the diagnostic 10.6 kb EcoRI fragment. A large-scale plasmid preparation was made from a colony containing the correct plasmid, which 25 was named pEP202. Plasmid pEP202 contains the complete *P. pastoris* *PEP4* gene (see Figure 2).

To facilitate sequence analysis of the cloned *P. pastoris* *PEP4* gene, a portion of the *P. pastoris* *PEP4* gene was subcloned into pUC19. Plasmid pEP202 was 30 digested with BamHI and EcoRI. The reaction mixture was separated on a 0.7% agarose gel, and the 0.45 kb BamHI

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fragment of DNA (see Fig. 2) was isolated using DE81 paper. The purified fragment was ligated to pUC19 (~20 ng) that had been linearized by digestion with BamHI and dephosphorylated. The ligation mixture was used to 5 transform *E. coli* strain MC1061. Transformants were selected for ampicillin resistance and screened by analysis of restriction enzyme digests of colony DNA for the presence of a single BamHI fragment. A single colony arising from this transformation was found to contain the 10 appropriate DNA construct, and was named pEP205 (see Figure 3).

Sequence analysis of plasmid pEP202 identified a DNA sequence with ~70% homology to the *PEP4* gene of *S. cerevisiae*. The amino acid sequence encoded by this DNA 15 sequence of pEP202 is 69% homologous to that encoded by the *S. cerevisiae* *PEP4* gene.

**EXAMPLE II: DEVELOPMENT OF A *PEP4*-DEFICIENT (*PEP4*<sup>-</sup>) STRAIN OF *P. PASTORIS***

20 **A. Construction of the *P. pastoris* *PEP4* Gene Disruption Vector pDR401**

Vector pDR401 was constructed for use in developing a *PEP4*-deficient (*PEP4*<sup>-</sup>) strain of *P. pastoris*. This 25 vector contains a defective *P. pastoris* *PEP4* gene, which, when used to transform *PEP4* strains of *P. pastoris*, integrates into the host genome by replacement of the wild-type *PEP4* gene.

pDR401 was constructed in a two-step procedure as follows. In the first step, the base vector in the 30 construction of pDR401, base vector pEP301, was constructed from pEP202. Vector pEP301 contains pUC19 sequences and the cloned *P. pastoris* *PEP4* gene from pEP202. Plasmid pEP202 (15 µg) was digested with SacI. A 5.5 kb SacI fragment (the fragment extending from the 35 SacI linker clockwise to the SacI site at ~5:00, and containing all of the pUC19 sequence and the entire *PEP4* gene; see Figure 2) was isolated from a 0.7% agarose gel

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using DE81 paper. The fragment was eluted from the paper with 400  $\mu$ l of 1 M NaCl, extracted with 400  $\mu$ l of phenol/chloroform and precipitated with ethanol. This DNA was then ligated with itself in a volume of 100  $\mu$ l containing 1  $\mu$ l of ligase and 1  $\mu$ l (~10 ng) of DNA. The ligation mixture was incubated at room temperature for 1 hr and then used to transform *E. coli* strain MC1061. Ampicillin-resistant colonies were selected and screened by analysis of restriction enzyme digests of colony DNA for the presence of a single 5.5 kb BglII fragment. Plasmid DNA was prepared from a transformed colony of MC1061 that contained the correct plasmid, which was named pEP301 (Figure 4).

In the second step of the construction of pDR401, the *P. pastoris* *HIS4* gene was inserted into the *PEP4*-containing plasmid pEP301 to yield the final vector. The *P. pastoris* *HIS4* gene was isolated on a 2.6 kb BglII fragment derived from pYJ8 $\Delta$ Cla [Cregg, J. *et al.* *Mol. Cell. Biol.* 5:3376-3385 (1985)]. Plasmid pYJ8 $\Delta$ Cla (15  $\mu$ g) was digested with BglII and the digested DNA was separated on a 0.7% agarose gel. The *HIS4* gene-containing 2.6 kb fragment was isolated with DE81 paper, eluted with 400  $\mu$ l of 1 M NaCl, extracted with 400  $\mu$ l of phenol/chloroform, precipitated with ethanol and resuspended in 10  $\mu$ l of water. Prior to inserting this 2.6 kb BglII fragment into the unique BglII site of pEP301, approximately 20  $\mu$ g of pEP301 were digested with BglII, dephosphorylated and extracted with phenol/chloroform. The 2.6 kb *HIS4*-containing fragment was then inserted into pEP301 by ligation of approximately 50 ng of the fragment to approximately 50 ng of the BglII-digested pEP301 in a total volume of 10  $\mu$ l containing 1  $\mu$ l of buffer, 1  $\mu$ l of ligase and water. Ligation was conducted at room temperature for 3 hrs and the ligation mix was used to transform MC1061 cells. Plasmid DNA

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prepared from an ampicillin-resistant colony was digested with BglII, SalI, BglII/SalI, PvuI, NcoI and KpnI to confirm the construction of pDR401. The restriction fragment pattern was consistent with that expected for 5 the correct plasmid pDR401 (see Figure 5). Plasmid pDR401 is pUC19 with the *P. pastoris* *HIS4* gene inserted at the unique BglII site within the *PEP4* structural gene, thus disrupting it.

10 **B. Transformation of *HIS4* *P. pastoris* Strain GS115 with a Fragment of pDR401**

In order to create a *PEP4* strain of *P. pastoris*, the *HIS4* *PEP4* *P. pastoris* strain GS115 (ATCC 20864) was transformed with 20 µg of the 5.3 kb EcoRI/SacI fragment of pDR401 according to the spheroplast method (see US 15 patent 4,879,231). This fragment of pDR401 consists of the *HIS4* gene-containing defective *PEP4* gene. Transformant strains resulting from this type of integration are prototrophic and can be distinguished from untransformed cells on this basis. The frequency of 20 transformation was approximately 10<sup>3</sup> µg<sup>-1</sup> DNA.

25 **C. Characterization of Transformants**

1. **Analysis of transformant carboxypeptidase Y activities**

His<sup>+</sup> transformants were subsequently analyzed for 25 carboxypeptidase Y activity using a colony overlay colorimetric screening procedure [see Jones, E. in *Genetics* 85: 23-33 (1977)]. In this assay, the His<sup>+</sup> transformant cells were released from the transformation 30 agar plates and grown on YEPD (yeast extract, 1% peptone, 2% dextrose and 2% agar) plates at a density of ~300 colonies per plate. The plates were overlayed with 0.6% agarose containing 40% dimethylformamide (DMF) to permeabilize the cells, and 1.2 mg/ml of the substrate APNE (N-acetyl DL phenylalanine  $\beta$ -naphthyl ester). 35 Because the cells were permeabilized, some of the vacuolar content of the cell was accessible to the

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reagent APNE. After the agarose overlay had solidified, the plates were soaked in a solution of 5 mg/ml Fast garnet salt. APNE is cleaved by the esterolytic activity of carboxypeptidase Y. The products of this reaction 5 bind the fast garnet salt to produce a red color in the colony. Colonies lacking carboxypeptidase Y activity do not bind the salt and therefore stain less intensely than do colonies that possess this activity. *PEP4*<sup>+</sup> colonies developed a red/pink center during the first 10-15 10 minutes after exposure to the garnet salt. In contrast, colonies defective at the *PEP4* locus were slow to develop this color and were distinguished as pink relative to the red *PEP4*<sup>+</sup> colonies. Colonies that appeared to have low carboxypeptidase Y activities based on the results of 15 this assay (*i.e.*, colonies that failed to develop a strong red color indicative of *PEP4*<sup>+</sup> colonies) were isolated, transferred to a master plate, subcultured along with control colonies and re-screened using the overlay assay. Twenty colonies which again failed to 20 develop a strong red color were selected for analysis by Southern blot hybridization to determine if the *PEP4* locus of these transformants had been disrupted by integration of the fragment of vector pDR401.

## 2. Southern blot hybridization analysis

25 Genomic DNA was extracted from 20 transformant strains that exhibited low carboxypeptidase activity, designated p1-p20, and digested with SacI and EcoRI. This procedure should liberate the *HIS4*-containing defective *PEP4* gene as the 5.3 kb EcoRI/SacI fragment that was used 30 to transform the strains. Two Southern blot filters were prepared from these digested DNAs; one blot was probed with a radiolabeled 1.4 kb XbaI/EcoRV fragment from pEP301 (see Fig. 4), which contained a portion of the cloned *P. pastoris* *PEP4* gene and the other blot was 35 probed with a radiolabeled 2.6 kb BglII fragment of

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pDR401 containing the *HIS4* gene. Control DNA from the transformation host strain GS115, which had been digested with SacI and EcoRI, was included in this analysis for comparative purposes.

5        Digestion of genomic DNA from GS115 with SacI and EcoRI yielded a 2.9 kb fragment that hybridized to the portion of the *PEP4* gene contained in the radiolabeled XbaI/EcoRV fragment of pEP301. In contrast, this probe hybridized to fragments of a different size in  
10      SacI/EcoRI-digested DNA from 19 of the 20 transformants analyzed. Only DNA from strain p17 yielded a hybridization pattern identical to that of DNA from the parental strain. The remaining 19 strains lacked a 2.9 kb hybridizing fragment characteristic of an undisrupted  
15      *PEP4* locus and contained an approximately 5.3 kb fragment and/or larger fragments that hybridized to the *PEP4* gene probe. The 5.3 kb fragment was the same size as the transforming DNA released from vector pDR401 upon digestion with SacI and EcoRI.

20       The results of Southern blot hybridization of DNA from strains p1-p16 and p18-p20 revealed that these strains contained a defective *PEP4* gene with an intact *HIS4* gene therein, and that the *PEP4* locus of the strains had been disrupted. Strain p13 was grown in a one-liter  
25      fermentation, as described in Example III, in order to analyze the proteolytic activity of the broth of a larger culture of a *PEP4* strain of *P. pastoris*.

3. Analysis of the transformant proteinase A activities

30       a. Protocol

The proteinase A activities of eight transformant strains were evaluated using an enzyme assay based on the method of Jones et al. [Genetics 102:655 (1982)]. Several control strains were also evaluated in this  
35      assay: *PEP4* and *PEP4* strains of *S. cerevisiae* (strains DBY747 and 20B12, respectively, from the Yeast Genetic

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Stock Center, University of California, Berkeley, CA) and a *PEP4* wild-type strain of *P. pastoris* (strain NRRL Y-11430 from the Northern Regional Research Center, Peoria, IL).

5       Proteinase A is a vacuolar enzyme responsible for the aspartyl protease activity encoded by the *PEP4* gene in *S. cerevisiae*. The procedure used to evaluate the proteinase activities of transformant cell extracts is based on the measurement of proteinase A-mediated release 10 of amino acids from acid-denatured hemoglobin. Transformant cell extracts were incubated with acid-denatured hemoglobin, and the proteinase A activity present in the extract was determined by estimating the difference in the amount of amino acid released at time 15 zero and after 90 minutes of incubation.

15       Cultures of the *S. cerevisiae* control strains DBY747 (*PEP4*) and 20B12 (*PEP4*), the *PEP4* *P. pastoris* strain NRRL Y-11430 and the experimental *PEP4* strains of *P. pastoris* were grown to stationary phase in YEPD medium. Cultured 20 cells (20 OD<sub>600</sub> units) were washed in 10 mM sodium azide and then lysed in 400  $\mu$ l of 100 mM Tris, pH 7.5, by vortexing the cells with acid-washed glass beads for one minute. The lysed cells were centrifuged in Eppendorf tubes for 10 minutes to remove cell debris. The 25 supernatant obtained after centrifugation (crude extract) was then examined for proteinase A activity as follows. Acid-denatured 1% hemoglobin (400  $\mu$ l) was added to 50  $\mu$ l of crude extract and incubated for 90 minutes at 37°C. Reactions were stopped by the addition of 0.2 ml of 1 N 30 perchloric acid. Insoluble material was removed by centrifugation, and 200  $\mu$ l of 0.31 M NaCl was added to 200  $\mu$ l of supernatant. A 40  $\mu$ l aliquot of this solution was then assayed using the Pierce BCA protein assay kit (see, for example, US Patent No. 4,839,295) for free 35 amino acids. The amount of free amino acids present in

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the sample that had been incubated for 90 minutes was compared to the amount present in a blank which consisted of a sample of a reaction mixture that was stopped at zero minutes. The relative difference in free amino acids between these two samples is a measure of 5 proteinase A activity.

**b. Results**

The results of proteinase A assays of control and transformant strains (see Table I;  $\Delta OD$  is a measure of the concentration of free amino acids in the sample) indicate that the proteinase A activity of the *PEP4* strain of *S. cerevisiae* represents only 10% of that of the *PEP4* strain of *S. cerevisiae*. Similarly, the proteinase A activities of the *PEP4* transformant strains (strains p1, p2, p5, p8, p13, p16 and p20) also are only approximately one-tenth of that of the *PEP4* strain of *S. cerevisiae*. The *PEP4* wild-type strain of *P. pastoris* displayed approximately half of the proteinase A activity of the *PEP4* strain of *S. cerevisiae*.

20

TABLE I  
PROTEINASE A ASSAY RESULTS

	<u>Strain</u>	<u>Phenotype</u>	<u>AOD/µg protein</u>
	DBY747 ( <i>S. cerevisiae</i> )	PEP4 <sup>+</sup>	28.1
	20B12 ( <i>S. cerevisiae</i> )	PEP4 <sup>-</sup>	2.7
25	<i>P. pastoris</i> control (NRRL Y-11430)	PEP4 <sup>+</sup>	13.1
	p13	PEP4 <sup>-</sup>	3.3
	p20	PEP4 <sup>-</sup>	4.2
	p17	PEP4 <sup>+</sup> (?)	7.5
30	p16	PEP4 <sup>-</sup>	0
	p16	PEP4 <sup>-</sup>	0
	p13	PEP4 <sup>-</sup>	3.3
	p8	PEP4 <sup>-</sup>	3.3
	p5	PEP4 <sup>-</sup>	5.0
35	p2	PEP4 <sup>-</sup>	6.6
	p1	PEP4 <sup>-</sup>	6.0

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The data obtained in proteinase A assays of *PEP4* *P. pastoris* strains generated by transformation of a *PEP4* strain with a defective *PEP4* gene are consistent with the results of Southern blot analyses of DNA from these 5 transformants which indicate that the *PEP4* locus of the transformants was disrupted upon transformation.

**EXAMPLE III: FERMENTATION OF A PEP4 STRAIN OF P. PASTORIS**

**A. Procedure**

A *PEP4* strain of *P. pastoris*, p13, generated by 10 transformation of strain GS115 with a defective *PEP4* gene-containing SacI/EcoRI fragment of vector pDR401, was grown in a one-liter fermentation according to a three-phase protocol consisting of a glycerol batch growth phase, a limited glycerol fed-batch phase and a methanol 15 fed-batch phase as follows.

A two-liter fermentor was autoclaved with 1000 ml of minimal salts medium (21 ml 85% phosphoric acid, 0.9 g calcium sulfate·2H<sub>2</sub>O, 14.3 g potassium sulfate, 11.7 g magnesium sulfate and 3.2 g potassium hydroxide) and 2% 20 glycerol. After sterilization, 4 ml PTM<sub>1</sub> trace salts solution (6 g/l cupric sulfate·5H<sub>2</sub>O, 0.8 g/l sodium iodide, 3 g/l manganese sulfate·H<sub>2</sub>O, 0.2 g/l sodium molybdate·2H<sub>2</sub>O, 0.02 g/l boric acid, 0.5 g/l cobalt chloride, 20 g/l zinc chloride, 65 g/l ferrous 25 sulfate·H<sub>2</sub>O, 0.2 g/l biotin and 5 ml sulfuric acid) were added to the fermentor and the pH was adjusted to 5 with concentrated NH<sub>4</sub>OH. The pH of the medium was maintained at 5 by addition of 50% NH<sub>4</sub>OH containing 0.1% Struktol J673 antifoam. Inocula were prepared from buffered yeast 30 nitrogen base (YNB) glycerol plates (phosphate-buffered YNB, 2% glycerol, 2% agar) and grown overnight at 30°C in phosphate-buffered YNB (11.5 g/L KH<sub>2</sub>PO<sub>4</sub>, 2.66 g/L K<sub>2</sub>HPO<sub>4</sub>, 0.67% yeast nitrogen base, pH 5) containing 2% glycerol. The fermentor was inoculated with 10-50 ml of the 35 cultured cells which had grown to an OD<sub>600</sub> of 1-8, and the

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batch growth regimen was continued for approximately one day until glycerol was exhausted. At the point of glycerol exhaustion, as indicated by increased dissolved oxygen, a glycerol feed (50% glycerol plus 12 ml/L of PTM<sub>1</sub>) was initiated at 10 ml/h and continued until 40 ml of glycerol feed had been added. After termination of the glycerol feed, a methanol feed (100% methanol plus 12 ml/L PTM<sub>1</sub>) was started at an initial rate of approximately 2 ml/h. After 3 hours, the methanol feed rate was increased to 6 ml/h. The methanol feed rate was maintained at 6 ml/h for 12-18 hours and was then increased to 10 ml/h and maintained at 10 ml/h for the duration of the fermentation. The vessel was harvested after 400 ml of methanol had been added to the fermentor.

15        **B. Sample Preparation**

Samples (15 ml aliquots) of the fermentor culture were removed from the fermentor at various time intervals throughout the course of the fermentation. Aliquots of each sample were centrifuged at 6500 x g for 5 minutes to 20 separate broth and cells. The levels of the NH<sub>4</sub>OH, antifoam, glycerol, and methanol reservoirs were recorded at these time points. Methanol and ethanol concentrations in the supernatant were determined by gas chromatography using a PorapakQ column (Alltech).

25        In addition, the wet weight of the culture was determined as an indicator of cell growth in the fermentor. For this purpose, a one ml aliquot of the fermentor culture was centrifuged for four minutes in a microfuge, the supernatant was decanted, and the wet 30 pellet was weighed.

**C. Results**

Growth of the PEP4 strain of *P. pastoris* p13 in a one-liter fermentation was monitored by determining the wet cell weight of the fermentor culture (in g/l) at 35 various times during the fermentation. A time course of

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the growth of strain p13 during the methanol fed-batch phase of the fermentation, when compared with the time course of the growth of the *HIS4 PEP4* strain G+PA0804H2 (generated by transformation of the *HIS4 PEP4* *P. pastoris* 5 strain GS115 with an expression vector containing the wild-type *HIS4* gene) during a similar one liter fermentation, demonstrates that the growth capabilities of the *PEP4* strain of *P. pastoris* are comparable to those of a *PEP4* strain.

10 **EXAMPLE IV: ANALYSIS OF THE PROTEOLYTIC ACTIVITY OF THE BROTH OF A PEP4 STRAIN OF P. PASTORIS GROWN IN A ONE-LITER FERMENTATION**

To determine if disruption of the *P. pastoris* *PEP4* gene was associated with a change in the proteolytic 15 activity of the broth of *P. pastoris*, the proteolytic activities of the broths from one-liter fermentations of a *PEP4* strain, strain p13, and a *PEP4* strain were compared. In this study, two different peptides, 20 epidermal growth factor (EGF; a recombinantly synthesized molecule consisting of the first 52 amino acids of the authentic 53 amino acid EGF molecule, as described in US patent application Serial No. 323,964) and growth hormone releasing factor (GRF; recombinantly synthesized as described in EP 206783) were separately incubated at room 25 temperature in cell-free broth from the one-liter fermentation of the *PEP4* *P. pastoris* strain p13, and in the cell-free broth from a similar one-liter fermentation of the *HIS4 PEP4* *P. pastoris* strain G+PA0804H2. After incubation for a specified period, aliquots of each 30 incubation mixture were examined by reverse phase high performance liquid chromatography (HPLC), described below, to determine the amount of intact peptide remaining in each sample and thereby determine the extent of proteolytic degradation of the peptide.

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A. Reverse-Phase High-Performance Liquid Chromatography (HPLC)

The reverse-phase HPLC system used in the analysis of EGF and GRF peptides in buffer and broth from fermentations of *P. pastoris* strains included a Waters 600 (Bedford, MA) solvent delivery system, Waters Model 481 Lambda Max variable wavelength detector, Wisp 710B autoinjector and a Shimadzu Chrom-Pac integrator (Cole Scientific, Moorepark, CA). Samples of broth from the fermentations of the *PEP4 P. pastoris* strain p13 and the *HIS4 PEP4 P. pastoris* strain G+PAO804H2 were diluted 1:10 in 0.1 M sodium phosphate, pH 5.0. Fifteen microliters of concentrated GRF stock was added to 285  $\mu$ l of diluted broth and incubated for four hours. A similar dilution of GRF stock in the phosphate buffer was also incubated for four hours as a control. Sixty microliters of EGF stock were added to 240  $\mu$ l of diluted broth or buffer and incubated for eight hours. Samples of each incubation mixture were separately injected into a Waters  $\mu$  Bondapak C18 reverse phase column. The peptides were eluted from the column in a 20-minute linear gradient of 20-60% mobile phase B (95% acetonitrile, 5% water, 0.1% trifluoroacetic acid). Mobile phase A (0.1% trifluoroacetic acid) was used to dilute mobile phase B in preparing the elution gradient.

B. Results

The amount of intact peptide (of the EGF or GRF molecules that were incubated in the fermentation broth of the *PEP4 P. pastoris* strain p13 and the broth of the *PEP4 P. pastoris* strain G+PAO804H2) was evaluated by comparing chromatograms obtained in HPLC analyses of intact EGF or GRF contained in 0.1 M sodium phosphate buffer, pH 5.0, and of EGF or GRF contained in broth. Chromatograms from HPLC analyses of the standard intact peptides consist of a major peak reflecting the amount of the standard peptide present in the sample and the

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retention time characteristic of the peptide. In contrast, proteolytic fragments of either peptide are retained on the HPLC column for varying lengths of time that differ from the retention time associated with the 5 intact peptide. Therefore, chromatograms from HPLC analysis of proteolytic fragments of either peptide (EGF or GRF) differ from chromatograms generated in HPLC analyses of intact peptides in terms of the number and sizes of the peaks and the retention times associated 10 with the fragmented species. Based on these differences, it was possible to estimate the amount of intact EGF or GRF peptide in the broth incubation samples.

Based on HPLC analyses of GRF and EGF samples incubated in *PEP4 P. pastoris* control broth, it has been 15 determined that less than 10% of each of the two peptides remains intact after incubation in broth from the fermentation of the *PEP4* strain G+PA0804H2. In contrast, the level of proteolytic degradation of these peptides in the broth of the *PEP4 P. pastoris* strain is significantly 20 less than that in the broth of the *PEP4* strain (GRF remained >60% intact, even after 4 hr incubation; EGF remained >90% intact, even after 8 hr incubation). These data demonstrate that disruption of the *PEP4* gene of *P. pastoris* results in a substantial reduction of the 25 proteolytic activity in the broth of the strain.

**EXAMPLE V: ISOLATION OF THE *P. PASTORIS URA3* GENE**

The *P. pastoris URA3* gene was identified in a plasmid (YEpl3)-based *Pichia* genomic library by its ability to complement the *pyrF* mutation (corresponding to 30 a defect in the orotidine monophosphate decarboxylase activity) in *E. coli* strain CSH-28. The *P. pastoris URA3* gene was cloned by isolating colonies of *E. coli* strain CSH-28 that had been transformed with library DNA and were capable of growth on media lacking uracil.

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**A. P. pastoris YEpl3 Genomic DNA Library**

Plasmid YEpl3 [Broach et al., Gene 8: 121-133 (1979)] is a convenient shuttle vector that contains an origin of replication for both *S. cerevisiae* ( $2\mu$  replicon) and *E. coli* (pBR ori). In addition, YEpl3 contains the Amp<sup>R</sup> (ampicillin resistance) gene for use as a selectable marker for transformation of *E. coli* and the *LEU2* gene (a leucine biosynthetic pathway gene) for use as a selectable marker in *S. cerevisiae*. A *P. pastoris* (strain NRRL Y-11430) genomic DNA library has been prepared using plasmid YEpl3, as described by Cregg et al. [Mol. Cell. Biol. 5: 3376-3385 (1985)].

**B. Screening of the *P. pastoris* YEpl3 Genomic DNA Library for the *URA3* Gene**

The *pyrF* *E. coli* strain CSH-28 [see Miller, J. H., in Experiments in Molecular Genetics, Cold Spring Harbor Laboratory Press, Cold Spring Harbor, New York (1972)] is defective for orotidine-5'-phosphate decarboxylase activity and requires uracil when grown on defined medium. It has been demonstrated that the *S. cerevisiae* *URA3* gene can complement the *pyrF* mutation in *E. coli* [Rose, M., Grisafi, P. and Botstein, D. Gene 29:113-124 (1984)]. Therefore, *E. coli* strain CSH-28 was transformed with DNA from the *P. pastoris* YEpl3 genomic DNA library in order to screen the library for the *P. pastoris* *URA3* gene capable of complementing the *pyrF* mutation of the strain.

Transformed CSH-28 cells were plated onto a semi-defined medium which did not contain uracil.

Untransformed cells would not grow on this medium. CSH-28 transformants (transformed with *P. pastoris* genomic library DNA) capable of growing on plates lacking uracil arose at a frequency of ~10/ $\mu$ g of transforming DNA. Plasmid DNA was isolated from ten of the transformants that did not require uracil for growth. These plasmids were used to transform *E. coli* strain

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CSH-28, and ten of ten plasmids complemented the uracil auxotrophy of this strain at high frequency. One of the selected transformants generated by transformation of CSH-28 with *P. pastoris* genomic library DNA harbored a 5 9.0 kb insert that contained a 6.6 kb SphI fragment. The 6.6 kb SphI fragment was subcloned into the SphI site of pUC19 for further analysis.

Plasmid DNA from this transformant was digested with SphI and subjected to electrophoresis on a 0.6% agarose 10 gel. The 6.6 kb fragment was isolated using DE81 paper and was eluted from the paper with 400  $\mu$ l of 1 M NaCl. DNA was extracted with 400  $\mu$ l of phenol/chloroform and precipitated with ethanol. The 6.6 kb fragment was then 15 ligated with 10 ng of alkaline phosphatase-treated, SphI-digested pUC19. The ligation mixture was used to transform *E. coli* MC1061 cells. Ampicillin-resistant transformants were screened by analysis of restriction enzyme-digested colony DNA for the presence of a 6.6 kb SphI fragment. The correct plasmid was called pPU201. 20 Plasmid pPU201 was used to transform CSH-28 and was able to complement the uracil auxotrophy of this strain.

**C. Characterization of the Insert in Plasmid pPU201**

A map of the restriction enzyme recognition sites of the 6.6 kb insert of *P. pastoris* DNA in plasmid pPU201 25 (Figure 6) was prepared by digesting pPU201 with a variety of enzymes and analyzing the resulting fragments using a DNA length computer program (MapSort; University of Wisconsin Genetics, Madison, WI) to determine the approximate sizes of the fragments. In order to 30 delineate the *URA3* gene contained in the 6.6 kb insert of pPU201, a 5 ng aliquot of each restriction enzyme digest of pPU201 was separated by electrophoresis on a 1% agarose gel, transferred to nitrocellulose, and probed with a radiolabeled 1.3 kb BglII fragment of the 35 *C. tropicalis* *URA3A* gene (see PCT Publication No. WO

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90/09449). The filters were hybridized to the probe at 27°C using a solution containing 25% formamide, 6x SSC, 5x Denhardt's solution, 20 mM Tris·HCl, pH 8.0, 1 mM EDTA, 0.1% sodium dodecyl sulfate (SDS) and 100 µg/ml salmon sperm DNA. After hybridization, the filters were washed three times at room temperature using 1x SSC and 1% SDS for 5-10 minutes per wash, and then washed twice with 0.5x SSC and 0.5% SDS at 45°C for 10 minutes per wash. These low stringency conditions permitted hybridization between divergent *URA3* gene sequences. Additional samples of each digest of pPU201 were separated on an identical 1% agarose gel and stained with ethidium bromide for comparison of hybridizing and non-hybridizing fragments. Comparison of the hybridizing fragments and the restriction map of pPU201 made it possible to localize the *URA3* gene in pPU201 to the approximately 1.3 kb NcoI-SalI fragment as shown in Figure 6. With this knowledge, it was then possible to construct subclones suitable for sequencing and further characterization of the *P. pastoris* *URA3* gene.

Plasmid pPU202 (Figure 7) was constructed by digesting pPU201 with EcoRV and PstI, isolating the approximately 4.0 kb fragment containing the *URA3* gene, and ligating it into pUC19 at the SmaI and PstI sites. Plasmids pPU203, pPU205 and pPU206 (Figures 8-10) were constructed by digesting pPU202 with SacI, KpnI and EcoRI, respectively, and then religating in a large volume (200 µl). Because there is a recognition site for each of these enzymes in the cloned *P. pastoris* genomic insert DNA fragment as well as the pUC19 polylinker of pPU202, this strategy allowed for the convenient removal of DNA between these sites in pPU202. The resulting plasmids were then used to transform *E. coli* strain CSH-28 to determine whether or not each deletion construct could complement the pyrF mutation. The results

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indicated that pPU203 and pPU205, but not pPU206, contained a functional *URA3* gene allowing growth of the *pyrF* strain on defined medium lacking uracil. These findings are consistent with the mapped position of the 5 *P. pastoris* *URA3* gene in pPU201.

The subclones of the *P. pastoris* genomic DNA fragment carrying the putative *URA3* gene were sequenced using the Sanger dideoxy method [see Sanger et al., Proc. Natl. Acad. Sci. USA 74: 5463-5467 (1977)]. The sequence 10 for the structural gene and approximately 100 bp of flanking sequence was determined in both directions and is presented in Sequence ID No. 3. The amino acid sequence deduced from the cloned *P. pastoris* *URA3* gene (see Sequence ID No. 4) has 73% homology with the amino 15 acid sequence deduced from the *S. cerevisiae* *URA3* gene, 71% homology with the amino acid sequence deduced from the *URA3A* and *URA3B* genes of *C. tropicalis* and 72% homology with the amino acid sequence deduced from the *URA3* gene of *Kleuveromyces lactis*.

20 **EXAMPLE VI: DEVELOPMENT OF IGF-1-EXPRESSING *PEP4*-DEFICIENT (*PEP4*<sup>-</sup>) STRAINS OF *PICHIA***

A. Generation of IGF-1-Expressing *PEP4* Strains by Gene Addition

25 1. Construction of the *P. pastoris* *PEP4* gene disruption vector pDR421

Plasmid pDR421 was constructed for use in the development of *PEP4*-deficient (*PEP4*<sup>-</sup>) strains of *Pichia pastoris* by disruption of a host *PEP4* gene through addition of an incomplete *PEP4* gene to the endogenous 30 *PEP4* locus. This vector contains an internal portion of the *PEP4* gene, which, when used to transform *PEP4* strains of *P. pastoris*, integrates into the host genome at the *PEP4* locus to generate two incomplete and nonfunctional copies of the *PEP4* gene.

35 In order to generate the disruption vector pDR421, the *URA3* gene of *Pichia* was cloned into vector pEP205

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(consisting of pUC19 sequences and the portion of the PEP4 gene contained in the ~450 bp BamHI fragment derived from pEP202). This was achieved by subcloning the URA3 gene from pPU205 (see Figure 9) as a 2 kb SpeI-SphI DNA 5 fragment into the XbaI-SphI sites of pEP205 (see Fig. 3).

Plasmid pPU205 was digested with SpeI and SphI and the reaction mixture was separated on a 0.8% agarose gel. The 2 kb DNA fragment containing the URA3 gene was isolated from the gel using DE81 paper, eluted and 10 purified. Plasmid pEP205 was digested with XbaI and SphI. The 2 kb URA3 gene-containing SpeI-SphI fragment isolated from pPU205 was ligated to XbaI/SphI-digested pEP205 and the mixture was used to transform *E. coli* strain MC1061 to ampicillin resistance. Ampicillin- 15 resistant colonies were screened by analysis of BamHI/SphI restriction enzyme-digested colony DNA for the presence of 2.7 kb, 0.4 kb and 1.9 kb diagnostic fragments. A transformant was found to harbor a plasmid with the correct DNA construct called pDR421 (Figure 11).

20 2. Transformation of an IGF-1-expressing URA3 *P. pastoris* strain (IGF-U) with pDR421

The URA3 IGF-1-expressing strain of *P. pastoris*, IGF-U, was transformed with pDR421 to generate PEP4-, IGF-1-expressing strains of *P. pastoris*.

25 a. Generation of IGF-U

5-Fluoro-orotic acid (5-FOA) is an analog of a uracil biosynthetic pathway intermediate that, when metabolized by Ura<sup>+</sup> strains, yields a toxic compound. Because the uracil biosynthetic pathway of Ura<sup>-</sup> strains is 30 blocked at certain steps, these strains do not metabolize 5-FOA (to produce a compound toxic to the cells) and are therefore 5-FOA resistant. In contrast, Ura<sup>+</sup> strains metabolize 5-FOA and cannot survive on 5-FOA-containing medium. Therefore, plating cells on 5-FOA-containing 35 medium can be used as a method to generate Ura<sup>-</sup> strains by

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spontaneous mutation [see, for example, Boeke et al.,  
Mol. Gen. Genet. 197: 345-346 (1984)].

A *URA3*<sup>+</sup> derivative of the IGF-1-producing strain  
G+IMB206S1 [for a description of this strain, see  
5 commonly assigned U.S. Patent Application Serial No.  
07/578,728, filed September 4, 1990, which is hereby  
incorporated by reference herein in its entirety] was  
generated by direct plating of  $\sim 5 \times 10^7$  cells this strain  
10 into 5-FOA-containing medium supplemented with uracil  
of 0.67% yeast nitrogen base, 2% agar, 2% glucose, 750 mg/l  
of 5-FOA and 48 mg/l of uracil). After one week of  
incubation at 30°C, a colony, designated IGF-U, growing  
on the plate was isolated. This colony, which required  
uracil in order to grow, was unable to complement a *URA3*  
15 strain of *Pichia pastoris*.

b. Transformation of IGF-U

Approximately 20 µg of pDR421 was digested with  
BglII was used to transform IGF-U using the standard  
spheroplast transformation procedure. Transformants were  
20 selected by their ability to grow in the absence of  
uracil over a 6 day period.

3. Characterization of transformants

a. Analysis of transformant carboxypeptidase Y  
activities

25 *Ura*<sup>+</sup> transformants were subsequently analyzed  
for carboxypeptidase Y activity using a colony overlay  
colorimetric screening procedure, as described in Example  
II. Colonies of *Ura*<sup>+</sup> transformants that appeared to have  
30 low carboxypeptidase Y activities based on the results of  
this assay (i.e., colonies that failed to develop a  
strong red color indicative of *PEP4*<sup>+</sup> colonies) were  
isolated, transferred to a master plate, subcultured  
along with control colonies and rescreened using the  
overlay assay. One colony which again failed to develop  
35 a strong red color was called M+IMB206S1.

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b. Analysis of intact IGF-1 expression levels of an IGF-1-expressing PEP4 strain of *P. pastoris* grown in one- and ten-liter fermentations

5 i. Fermentation of an IGF-1-expressing PEP4 strain of *P. pastoris*

An IGF-1-expressing PEP4 strain of *P. pastoris*, M+IMB206S1, generated as described in Example VI.A.2.b., was grown in one- and ten-liter fermentations according to a three-phase protocol consisting of a glycerol batch 10 growth phase, a limited glycerol fed-batch phase and a methanol fed-batch phase. In order to compare the intact IGF-1 expression levels of PEP4 and PEP4 IGF-1-expressing strains of *P. pastoris*, two PEP4 strains of *P. pastoris*, G+IMB204S14 and G+IMB206S1, containing four and six 15 copies of an IGF-1 gene expression cassette, respectively (see, U.S. application Serial No. 07/578,728), were also grown in comparable fermentations as follows.

One-liter fermentation protocol

A two-liter fermentor (Biolafitte, Princeton, NJ) 20 was autoclaved with 900 ml of minimal salts medium (21 ml 85% phosphoric acid, 0.9 g calcium sulfate·2H<sub>2</sub>O, 14.3 g potassium sulfate, 11.7 g magnesium sulfate, and 3.2 g potassium hydroxide) and 30 g of glycerol. After sterilization, 4 ml PTM, trace salts solution (6 g/l 25 cupric sulfate·5H<sub>2</sub>O, 0.08 g/l sodium iodide, 3 g/l manganese sulfate·H<sub>2</sub>O, 0.2 g/l sodium molybdate·2H<sub>2</sub>O, 0.02 g/l boric acid, 0.5 g/l cobalt chloride, 20 g/l zinc chloride, 65 g/l ferrous sulfate·H<sub>2</sub>O, 0.2 g/l biotin and 5 ml sulfuric acid) were added to the fermentor and the 30 pH was adjusted to 5 with concentrated NH<sub>4</sub>OH. The pH was controlled by addition of 50% NH<sub>4</sub>OH containing 0.1% Struktol J673 antifoam (added to control foaming). The 35 temperature was maintained at 30°C, and dissolved oxygen was maintained above 20% of saturation by increasing agitation, aeration, or the supplementation of the air feed with oxygen.

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Inocula were prepared from cells grown overnight at 30°C in buffered YNB containing 2% glycerol. The fermentor was inoculated with 40-70 ml of the cultured cells which had grown to an OD<sub>600</sub> of 2-8, and the batch 5 growth regimen was continued for 18-24 hours until glycerol was exhausted. At the point of glycerol exhaustion, indicated by an increase in dissolved oxygen concentration, a glycerol feed (50% w/v glycerol plus 12 ml/L PTM<sub>1</sub>) was initiated at 10 ml/hr. In pH 5.0 10 fermentations, the pH of the culture was maintained at 5 throughout the fermentation. In low pH fermentations (i.e., pH 2.8 or pH 3.5), the set point of the pH controller was adjusted to the desired pH after initiation of the glycerol feed. After four hours, the 15 pH of the culture decreased to the set point value as a result of cellular metabolism. This lower pH was then maintained throughout the remainder of the fermentation. The glycerol feed was then terminated and a methanol feed (100% methanol plus 12 ml/L PTM<sub>1</sub>) was initiated at a rate 20 of 2 ml/hr. After three hours of methanol feeding, the feed rate was increased to 6 ml/hr and maintained at this rate for the remainder of the fermentation. The vessel was harvested 72 hours after initiation of the methanol feed.

25 The fermentation was monitored in terms of NH<sub>4</sub>OH, antifoam, glycerol, methanol, ethanol, and wet cell weight levels as described in Example III. Broth and cell samples were collected throughout the fermentation as also described in Example III.

30 Ten-liter fermentation protocol

A 15-liter fermentor containing 3.5 liters of 10X basal salts (42 ml 85% phosphoric acid/l, 1.8 g calcium sulfate·2H<sub>2</sub>O/l, 28.6 g potassium sulfate/l, 23.4 g magnesium sulfate/l, 6.5 g potassium hydroxide/l) and 35 220 g glycerol in a total volume of 5.5 liters was

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sterilized. After the fermentor had cooled, 24 ml PTM<sub>1</sub> trace salts were added and the pH was adjusted to 5.0 with the addition of 28% ammonium hydroxide. The pH was controlled by the addition of the same solution. Foaming 5 was controlled with the addition of a 5% solution of Struktol J673. Temperature was maintained at 30°C, and dissolved oxygen was maintained above 20% of saturation by increasing agitation, aeration, reactor pressure or by supplementation of the air feed with oxygen. Inocula 10 were prepared from *P. pastoris* cells grown overnight in buffered yeast nitrogen base (YNB; 11.5 g/L KH<sub>2</sub>PO<sub>4</sub>, 2.66 g/L K<sub>2</sub>HPO<sub>4</sub>, 6.7 g/L yeast nitrogen base, pH 6) containing 2% glycerol. The fermentor was inoculated 15 with 500-700 ml of the cultured cells which had grown to an OD<sub>600</sub> of 2-8, and the batch growth regime was continued for 18-24 hours. At the point of glycerol exhaustion, indicated by an increase in dissolved oxygen 20 concentration, a glycerol feed (50% w/v glycerol plus 12 ml/L PTM<sub>1</sub>) was initiated at 100 ml/hour and continued for 4 hours. The glycerol feed was then terminated and a methanol feed (100% methanol plus 12 ml/L PTM<sub>1</sub>) was 25 initiated at 20 ml/hr. With the initiation of the methanol feed, the set point of the pH controller was adjusted to 2.8. The pH then gradually decreased to the set point value as a result of cellular metabolism. After 4 hours of methanol feeding, the methanol feed rate was increased to 60 ml/hour and maintained at this rate for a total of approximately 72 hours, at which point the vessel was harvested.

30                   ii. IGF-1 expression levels of PEP4 and PEP4 IGF-1-expressing strains

One of the several forms of IGF-1 produced in fermentations of recombinant IGF-1-secreting strains of *P. pastoris* is a nicked species consisting of two or more 35 fragments of the IGF-1 molecule held together by

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disulfide bonds. The fragments are generated by proteolytic cleavage of one or more peptide bonds of the amino acid backbone of the IGF-1 molecule. Although nicked and intact IGF-1 molecules are indistinguishable 5 on the basis of apparent molecular weight [under non-reducing conditions, as determined by SDS-polyacrylamide gel electrophoresis (SDS-PAGE)], these species can be resolved by reverse phase HPLC under non-reducing conditions and by SDS-PAGE under reducing conditions 10 (i.e., in the presence of a reducing agent such as dithiothreitol). Reduction of the disulfide bonds holding the fragments of nicked IGF-1 together results in liberation of the individual proteolytically generated IGF-1 fragments which have smaller molecular weights than 15 the intact molecule.

Quantitation of IGF-1 expression levels

The yields of nicked and authentic (intact, correctly folded, monomeric) IGF-1 in the cell-free broth were determined by quantitative reverse phase HPLC. The 20 HPLC system that was used was the same as that described in Example IV, except a Vydac C4 column (0.46 x 5 cm) was employed instead of a C18 column. A 1%/minute gradient of 25-42% mobile phase B was passed through the column during a period of 17 minutes at a flow rate of 1 25 ml/minute to elute samples from the column. The detector was set at 0.05 absorbance units full scale (AUFS), and a wavelength of 215 nm was used for maximum sensitivity.

To distinguish the authentic and nicked IGF-1 species in *P. pastoris* broth by HPLC, it was necessary to 30 clean-up the broth by removing some endogenous *P. pastoris* contaminants from the broth prior to loading broth samples onto the HPLC column. This was accomplished by passing the broth through a sulphopropyl-based cation exchange resin contained in a 0.25 ml 35 column. The resin was first washed with 2 ml of 0.2 M

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acetic acid, then equilibrated with 2 ml of 0.02 M acetic acid. A volume of crude cell-free broth (1 ml) was loaded onto the column which was then washed with 1 ml of 0.02 M acetic acid. The IGF-1 was eluted with 2 ml of 5 0.02 M sodium acetate, pH 5.5, plus 1 M NaCl. The first 1 ml of eluate contained 75-80% of the total IGF-1 and was usually the only elution volume collected. The column was then regenerated by washing with 2 ml of 100% methanol and thereby available for re-use.

10 In order to quantitate the levels of Pichia-produced IGF-1, known amounts of standard IGF-1 (Amgen, Thousand Oaks, CA) were injected into the HPLC column and the area under the corresponding peaks in the chromatograms was measured. A standard curve was generated by plotting 15 area versus  $\mu$ g of IGF-1 loaded onto the HPLC column. A correlation coefficient for use in converting the area under HPLC chromatogram peaks to IGF-1 concentration was calculated from the standard curve. When the detector was set at 0.05 AUFS and a wavelength of 215 nm, the 20 correlation coefficient was 350 units/ $\mu$ g of IGF-1 injected onto the column. Using this information, it was possible to determine the concentration of correctly folded, intact monomeric IGF-1 present in a cleaned-up broth sample by measuring the area under the 25 corresponding peak on the chromatogram from HPLC analysis of the sample. This correlation coefficient was also used to estimate the approximate concentration of the nicked IGF-1 species as well. However, the absolute concentrations of the nicked species may vary depending 30 on differences in the specific correlation coefficients of intact and nicked IGF-1.

Results of one-liter fermentations

One-liter low pH (pH 2.8) fermentations of the PEP4 IGF-1-expressing strain consistently yielded greater 35 amounts of total monomeric (authentic plus nicked) IGF-1

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(-200-250 mg/l) than one-liter low pH fermentations of the *PEP4* IGF-1-expressing strains (-160-190 mg/L). Furthermore, the percentage of authentic IGF-1 in the broth of the *PEP4* strain was somewhat higher (77%) than 5 that in the broth of the *PEP4* strains (65%). However, a much more dramatic difference in the monomeric IGF-1 production levels of the *PEP4* and *PEP4* strains was detected in pH 5.0 fermentations of these strains. Essentially no IGF-1 was detected in one-liter pH 5.0 10 fermentations of the *PEP4* IGF-1-expressing strains G+IMB204S14 and G+IMB206S1. This result indicates that the authentic IGF-1 produced in fermentations of *PEP4* strains is subjected to extensive proteolysis at pH 5.0, but to only limited proteolysis at lower pH. In 15 contrast, one-liter pH 5.0 fermentations of the *PEP4* IGF-1-expressing strain M+IMB206S1 yielded at least 200 mg of monomeric IGF-1/l, approximately 80% of which was authentic IGF-1. The *PEP4* IGF-1-expressing strain thus appears to be significantly improved relative to the *PEP4* 20 IGF-1-expressing strains for production of authentic IGF-1 at pH 5.0 and somewhat improved for production of authentic IGF-1 at pH 2.8.

Results of ten-liter fermentations

Ten-liter fermentations of the *PEP4* IGF-1-expressing 25 strain of *P. pastoris* yielded greater amounts of total monomeric IGF-1 (~200 mg/l) than did ten-liter fermentations of the *PEP4* IGF-1-expressing strains (~170 mg/l).

The compositions of the total monomeric IGF-1 30 produced in 10-liter fermentations of the *PEP4* and *PEP4* strains also differed. Greater than 75% (164 mg/l) of the total monomeric IGF-1 in the 10-liter fermentation of the *PEP4* strain M+IMB206S1 was authentic IGF-1, whereas only about 50% (88 mg/l) of the total monomeric IGF-1 in

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the 10-liter fermentation of the *PEP4* strain G+IMB204S14 was authentic IGF-1.

Furthermore, because the cell yield in the fermentation of the *PEP4* strain was ~30% less than the 5 cell yield in the fermentation of the *PEP4* strain, the per cell yield of authentic IGF-1 was greatly enhanced in the fermentation of the *PEP4* strain. As a consequence of lower cell yield in the fermentation of the *PEP4* strain, a greater volume of cell-free broth was recovered from 10 the fermentation of the *PEP4* strain (relative to the volume of cell-free broth recovered from the fermentation of the *PEP4* strain). This results in the recovery of higher levels of secreted IGF-1 from the fermentation of the *PEP4* strains (relative to the amount of secreted 15 IGF-1 recovered from the fermentation of the *PEP4* strain).

The results presented above demonstrate that the *PEP4* IGF-1-expressing strain is improved, relative to the *PEP4* IGF-1-expressing strain, for production of authentic 20 IGF-1 on a large scale.

**B. Generation of an IGF-1-Expressing *PEP4* Strain by Gene Replacement**

**1. Construction of the *P. pastoris* gene disruption vectors pDR601 and pDR602**

25 Vectors pDR601 and pDR602 were used in the development of *PEP4*-deficient (*PEP4*<sup>-</sup>) strains of *P. pastoris* by disruption of a host *PEP4* gene through replacement of the endogenous *PEP4* gene with a defective *PEP4* gene. This vector was constructed in several steps 30 as follows (see also diagram in Figure 13).

Plasmid pEP301 (see Figure 4), consisting of pUC19 sequences and the cloned *P. pastoris* *PEP4* gene from pEP202, was cleaved with NcoI, and the DNA was then precipitated with ethanol, harvested, resuspended and 35 ligated in ligation reaction mixture. This digestion and ligation effectively removed an internal portion of the

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PEP4 gene contained in an ~0.5 kb NcoI fragment. After ligation, the DNA was digested with BglII to linearize any remaining parental plasmid, and the DNA was used to transform *E. coli* strain MC1061. Ampicillin-resistant 5 colonies were selected and screened by analysis of restriction enzyme digests of colony DNA for the presence of a 0.5 kb NcoI fragment. The correct plasmid, containing the defective PEP4 gene lacking an ~0.5 kb NcoI fragment, was named pDL321. A second plasmid, 10 pUC19XX, was generated by cleaving pUC19 with SmaI and HincII and religating, effectively removing a portion of the polylinker containing the BamHI and XbaI sites. Plasmid pUC19XX was then cut with SacI and EcoRI and ~10 ng was ligated with ~50 ng of the SacI/EcoRI 2.2 kb 15 fragment of pDL321, which had been gel-purified and isolated with DE81 paper. The ligation mix was used to transform MC1061 cells, and ampicillin-resistant colonies were screened by analysis of BstIII/XbaI-digested colony DNA. Plasmid showing the correct digest pattern was 20 designated pDL322.

pDL322 was then cut with XbaI and 10 ng were ligated with 10 ng of an oligonucleotide linker of the sequence 5'-CTAGCGGCCG-3', which destroyed the XbaI site and generated a unique NotI site when ligated into the XbaI 25 site. The ligation mix was used to transform MC1061 cells. Ampicillin-resistant colonies were screened by analysis of NotI-digested colony DNA. The correct plasmid was called pDL323.

To generate vectors pDR601 and pDR602, the *Pichia* 30 URA3 gene was inserted into pDL323 as follows. Plasmid pPU205 (see Figure 9) was digested with PvuII and AatI to liberate the URA3 gene on an approximately 2.5 kb PvuII fragment. The digest was separated on a 0.8% agarose gel. The ~2.5 kb fragment was isolated from the gel 35 using DE81 paper, eluted and purified. Plasmid pDL323

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was linearized by cutting it with EcoRV. This linearized plasmid (~10 ng) was ligated with the *URA3*-bearing PvuII fragment of pPU205 to generate pDR601 and pDR602 (see Figures 14 and 15, respectively), depending upon the 5 orientation of the inserted *URA3* gene.

**2. Transformation of IGF-U with pDR601 and pDR602**

The *URA3* IGF-1-expressing *P. pastoris* strain IGF-U (see Example VI.A.2.a.) was transformed with linear 10 fragments of DNA derived from pDR601 and pDR602. The linear fragments contained the *URA3* gene flanked on each side with DNA coding for a portion of the *PEP4* gene. Homology between the ends of the fragments and the *PEP4* gene stimulated integration of the fragments at the *PEP4* 15 locus resulting in a gene replacement event. Stable integration of either fragment into the host genome yielded prototrophic transformants due to the stable presence of the *URA3* gene contained in the fragments. The transformation was conducted as follows:

20 Linear DNA fragments (~4.0 kb in length), consisting of the *URA3* gene flanked on each side with DNA coding for a portion of the *PEP4* gene, were obtained by digesting both pDR601 and pDR602 with NotI and BstIII. The digested DNA (20 µg) was used to transform strain IGF-U 25 using the standard spheroplast procedure. *Ura*<sup>+</sup> colonies isolated from transformants growing on regeneration medium and subcultured onto YEPD medium were screened for carboxypeptidase Y activity using the overlay procedure described in Example II. Colonies that did not develop a 30 red color relative to control colonies were selected for analysis by Southern blot hybridization.

**3. Southern blot hybridization of DNA from transformants**

Genomic DNA was isolated from the selected 35 transformants using the method of Hoffman and Winston [Gene 57: 267-272 (1987)]. Genomic DNA from each strain

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was digested with BstEII. This procedure liberates a portion of the *PEP4* locus containing the region of integration of fragments of pDR601 or pDR602. Therefore, the size of this region is diagnostic for correct 5 integration of the transforming DNA into the genome of IGF-U. The digested DNA was subjected to electrophoresis on a 0.8% agarose gel and blotted to a nitrocellulose filter. The filter was hybridized with a radiolabeled 1.4 kb XbaI/EcoRV fragment of pEP301 which contains part 10 of the *P. pastoris* *PEP4* gene using standard procedures [Maniatis, T., Fritsch, E.F. and Sambrook, J. Molecular Cloning, A Laboratory Manual, pp 385-388, Cold Spring Harbor Laboratory Press, Cold Spring Harbor, N.Y., USA. (1982)]. Hybridization was conducted at 37°C in a 15 solution containing 50% formamide, 6 X SSC, 5X Denhardt's solution, 20 mM Tris HCl, pH 8.0, 1 mM EDTA, 0.1% SDS and 100 µg/ml salmon sperm DNA. The filter was then washed three times in 1 x SSC, 0.1% SDS (10 min per wash) and then in 0.5 x SSC, 0.1% SDS at 65°C for 1 hr. As a 20 comparative control, genomic DNA from *P. pastoris* strain GS115, a *PEP4* strain, was included in this analysis.

Digestion of genomic DNA from GS115 with BstEII yielded a 4.4 kb fragment that hybridized to the portion of the *PEP4* gene contained in the probe. In contrast, 25 this probe hybridized to a 6.9 kb fragment in DNA from at least two of the transformants, IGFU2601-5 and IGFU2602-5. The larger size of the transformant *PEP4* locus as compared to the control *PEP4* locus (6.9 vs. 4.4 kb) is consistent with replacement of the host *PEP4* gene with a 30 nonfunctional *PEP4* gene carrying the *URA3* gene within its structural region.

From these results, it was concluded that strains IGFU2601-5 and IGFU2602-5 were examples of the several *PEP4* strains generated by disruption of the *PEP4* gene of 35 host strain IGF-U through gene replacement.

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**EXAMPLE VII: GENERATION OF A PEP4- PICHIA STRAIN USING  
"POPOUT" VECTORS**

**1. Construction of P. pastoris gene disruption  
vector pDL521**

5 Vector pDL521 was used in the development of *PEP4*-deficient (*PEP4*<sup>-</sup>) strains of *P. pastoris* by disruption of a host *PEP4* gene through "pop-in/pop-out" methods. In this method, a defective *PEP4* gene containing a small deletion is added to a host *PEP4* locus, and a functional 10 *PEP4* gene is removed from the *PEP4* locus (i.e., pop-in/pop-out).

pDL521 was constructed in two steps. First, an intermediate plasmid, pDL501, was constructed by ligation of the 2.2 kb EcoRI/SacI fragment of pDL323, the 2.2 kb 15 SacI/PstI fragment of pPU205 and the 2.7 kb EcoRI/PstI fragment of pUC19 in a three-way ligation. These three fragments were obtained as follows. pPU205, which contains the *P. pastoris* *URA3* gene (Figure 9), was digested with PstI and SacI. A 2.2 kb PstI-SacI fragment 20 containing the *URA3* gene was gel isolated and purified using DE81 paper. Plasmid pDL323, harboring a defective *PEP4* gene which lacks a 0.5 kb NcoI fragment present in an intact *PEP4* gene (see Fig. 13), was digested with EcoRI and SacI. A 2.2 kb fragment containing the 25 defective *PEP4* gene was gel isolated and purified using DE81 paper. pUC19 was digested with EcoRI and PstI. The three fragments (0.02  $\mu$ g of the EcoRI/PstI-digested pUC19, 0.02  $\mu$ g of the 2.2 kb PstI/SacI fragment of pPU205 and 0.02  $\mu$ g of the 2.2 kb EcoRI/SacI fragment of pDL323) 30 were ligated in a three-way ligation. The ligation mix was used to transform *E. coli* strain MC1061. Ampicillin-resistant colonies were screened by analysis of NcoI-digested colony DNA. Plasmid containing the correctly ligated fragments was called pDL501. pDL501 was then cut 35 with SacI, treated with calf alkaline phosphatase and 0.02  $\mu$ g were ligated with 0.02  $\mu$ g of a 1.9 kb SacI

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fragment isolated from SacI-digested pEP202 and purified using DE81 paper. This added more *PEP4* flanking sequence to the 3' end of the defective *PEP4* gene in pDL501 and ensured a greater amount of homologous sequence for  
5 recombination with the endogenous *PEP4* gene during transformation of *P. pastoris* host IGF-U. The ligation mix was used to transform *E. coli* strain MC1061. DNA from ampicillin-resistant colonies was digested with BglIII and SpeI and screened for the presence of the  
10 diagnostic 0.8 kb fragment indicative of the presence of the added SacI fragment from pEP202. Correct plasmid was called pDL521 (see Figure 16).

2. Transformation of GS4-2 with pDL521

a. Generation of GS4-2

15 A *URA3* strain of *P. pastoris* was required as a host in the generation of a *PEP4* strain by the pop-out process. A *URA3* strain was developed by direct plating of  $10^6$  cells of the general *HIS4* *P. pastoris* host strain GS115 in 5-fluoroorotic acid medium supplemented with  
20 uracil (0.67% yeast nitrogen base, 2% agar, 2% glucose, 750 ng 5-FOA/l and 48 mg uracil/l). After one week of incubation at 30°C, a colony growing on the plate was isolated. This His<sup>+</sup>Ura<sup>-</sup> strain was named GS4-2.

25 b. Transformation of GS4-2 and generation of a *PEP4* strain

Plasmid pDL521 was linearized by digestion with NotI. The NotI site is located immediately 5' of the site at which sequence had been deleted from the *PEP4* gene to make it defective. The ends of the NotI fragment  
30 are homologous to sequences in the endogenous *PEP4* gene of GS4-2, which promotes integration of the fragment by homologous recombination at the *PEP4* locus.

The His<sup>+</sup> Ura<sup>-</sup> strain GS4-2 was transformed according to the spheroplast method with 20  $\mu$ g of pDL521 which had  
35 been linearized by digestion with NotI. Transformants were selected by their ability to grow on media lacking

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uracil. Twelve of these transformants were picked, genomic DNA isolated from these transformants (as described in Example VI.B.3.), cut with Sall and subjected to electrophoresis on a 0.8% agarose gel. The 5 DNA was transferred to a nitrocellulose filter and probed with a radiolabeled 1.2 kb EcoRV/XbaI fragment of the *PEP4* gene. Two strains, GS4-2521-3 and GS4-2521-4, which appeared to have integrated pDL521 into the *PEP4* locus, based on the Southern blot hybridization pattern of 10 genomic DNA, were chosen for further selection. These strains contained the *URA3* marker gene with an intact complete *PEP4* gene on one side and a defective *PEP4* gene (lacking ~0.5 kb of sequence) on the other side of the marker gene. This configuration of the *PEP4* locus 15 permits recombination between the two copies of the *PEP4* gene that would result in elimination of one of the *PEP4* genes and the *URA3* gene (i.e., pop-out). Either one of the two *PEP4* genes could be evicted in this recombination event. To identify if, and when, recombination between 20 the two *PEP4* genes occurred, strains GS4-2521-3 and GS4-2521-4 were plated onto YPD medium containing 5-FOA in a serial 10-fold dilution manner. Only Ura<sup>+</sup> strains grow in the presence of 5-FOA, and thus growth in such medium indicates the occurrence of the desired 25 recombination event. Strains able to grow on 5-FOA-containing medium were uracil auxotrophs generated by recombination between the two copies of the *PEP4* gene. Ura<sup>+</sup> colonies appeared on the 5-FOA-containing plate after 1 week of culture at 30°C: 10 of these colonies were 30 derived from GS4-2521-3, and 14 of these colonies were derived from GS4-2521-4.

### 3. Characterization of transformants

Fourteen of the Ura<sup>+</sup> transformant colonies were purified, genomic DNA was prepared from each, digested 35 with EcoRI and EcoRV, subjected to electrophoresis on a

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0.8% agarose gel, blotted to nitrocellulose and hybridized with a radiolabeled 1.2 kb XbaI/EcoRV fragment of the *P. pastoris* *PEP4* gene. DNA from 7 of the 14 isolates analyzed in this way had a hybridization profile consistent with a *PEP4* locus consisting of only a defective *PEP4* gene lacking ~0.5 kb of sequence present in an intact *PEP4* gene. Two of these strains are GS4-2521-3/7 and GS4-2521-4/1.

**EXAMPLE VIII: CLONING OF A PORTION OF THE PRB-1 GENE OF *P. PASTORIS***

The proteinase B gene, *PRB-1*, encodes a vacuolar serine endoprotease in *S. cerevisiae* [Moehle et al., *Mol. Cell Bio.* **7**: 4390-4399 (1987)]. A portion of the equivalent gene was cloned from *P. pastoris* using 15 polymerase chain reaction (PCR) gene amplification techniques [see, for example, Gould et al., in *Proc. Natl. Acad. Sci. USA* **86**: 1934-1938 (1989)]. Degenerate oligonucleotides, which had homology to sequences of the *PRB-1* gene that encode regions of the proteinase B 20 protein which are conserved across species (Moehle et al. *supra.*) were synthesized for use as primers in the PCR amplification of *P. pastoris* *PRB-1* DNA. The oligonucleotides had the following sequences:

### Oligonucleotide 1:

25 A A A G  
 5' - GATAGAATTCTGCAG GGT AAT GGT CAT GGT ACT CAT TGT GC-3'  
 C C C C C C C C C  
 A

**Oligonucleotide 2:**

To facilitate subcloning of the amplified DNA fragments into shuttle plasmids, each oligonucleotide also contained one or more restriction endonuclease recognition sites on its 5' end: a SphI site on oligonucleotide 2 and both PstI and EcoRI sites on oligonucleotide 1.

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The PCR reaction medium consisted of 100 ng of *P. pastoris* (Strain NRRL Y-11430) genomic DNA in 2  $\mu$ l of T.E. (10 mM Tris-HCl, 1 mM EDTA), 10  $\mu$ l of oligonucleotide 1 and 10  $\mu$ l of oligonucleotide 2, 16  $\mu$ l 5 of a 1.25 mM solution of dGTP, dCTP, dATP, and dTTP, 10  $\mu$ l of 10x buffer (500 mM KCl, 100 mM Tris-HCl, pH 8.3, 15 mM MgCl<sub>2</sub>), 0.1% gelatin, 70  $\mu$ l of water and 0.5  $\mu$ l of 5 units/ $\mu$ l Tag DNA polymerase. The solution was heated 10 at 94°C for 2 minutes. The PCR cycling reaction, which was repeated 31 times, included denaturating for 2 minutes at 96°C, annealing for 1 minute at 50°C and 15 polymerizing for 3.5 minutes at 72°C.

The product of this PCR was subjected to 20 electrophoresis on an agarose gel, and a fragment of the size predicted (~500 bp) for the product of amplification of the PRB-1 gene between positions corresponding to 25 oligonucleotides 1 and 2 was isolated on DE81 paper, and digested with EcoRI and SphI, subjected to electrophoresis on an agarose gel. The 500 bp fragment was isolated using DE81 paper and was ligated into 10 ng 30 of pUC19, which had been linearized by cutting with EcoRI and SphI in the polylinker. The ligation mix was used to transform *E. coli* MC1061 cells. Restriction enzyme-digested plasmid DNA from ampicillin-resistant 35 transformants was analyzed for the presence of the correct 500 bp EcoRI-SphI fragment. One colony contained the correct plasmid, designated pPRBPP. A restriction map of the *Pichia* portion of this plasmid is set forth in Figure 17.

The sequence of the cloned portion of the 30 *P. pastoris* PRB-1 gene contained in pPRBPP was generated using the Sanger dideoxy method (see Sanger et al., supra) and is shown in Sequence ID No. 5. This sequence of the *P. pastoris* PRB-1 gene has approximately 74% 35 homology to the sequence of the *S. cerevisiae* PRB-1 gene.

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**EXAMPLE IX: DEVELOPMENT OF A PRB-1 STRAIN OF P. PASTORIS**

Plasmid pDR911 was constructed for use in developing PRB-1 strains of *P. pastoris*. This vector contains an internal portion of the *P. pastoris* PRB-1 gene, which, 5 when used to transform PRB-1 strains of *P. pastoris*, integrates into the host genome at the PRB-1 locus to generate two incomplete and non-functional copies of the PRB-1 gene. Vector pDR911 also contains a complete functional *P. pastoris* URA3 gene for use as a selectable 10 marker in URA3 host strains of *P. pastoris*.

**A. Construction of pDR911**

The PRB-1 gene fragment of *P. pastoris* in pPRBPP was isolated by restriction digestion of pPRBPP with PstI and SphI. The reaction mixture was loaded onto a 0.8% agarose 15 gel and the 0.5 kb fragment was purified with DE81 paper.

This 0.5 kb fragment was ligated into a linear form of plasmid pPU203, a *P. pastoris* URA3-containing pUC-based plasmid (see Figure 8). Plasmid pPU203 was linearized by cleavage with SphI and PstI, and ~10 ng was 20 ligated with ~100 ng of the *Pichia* DNA fragment. The ligation mixture was used to transform *E. coli* strain MC1061 to ampicillin resistance. Ampicillin-resistant colonies were screened by analysis of PstI/SphI-digested colony DNA for the diagnostic fragment. Correct plasmid 25 was named pDR911 (see Figure 18).

**B. Transformation of GS4-2 with pDR911**

To generate PRB-1 strains of *P. pastoris*, one could transform GS4-2 by standard spheroplast transformation with pDR911 that had been linearized by digestion with 30 BglII. Southern blot hybridization of DNA from Ura<sup>+</sup> transformants would enable confirmation of PRB-1 strains created by disruption of the PRB-1 locus. Proteinase B activity assays [see, for example, Jones et al., in *Genetics* 102: 665-677 (1982)] of transformants would

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further confirm the proteinase B deficiency of the strains.

**C. Development of a prb-1, pep4 strain of *P. pastoris***

5        The PRB-1 gene of the pep4, ura3, his4 strain of *P. pastoris* GS4-2521-4-5, which is an isolate of GS4-2521-4 (see Example VII), was disrupted by transformation with the vector pDR911, which had been linearized by cleavage with BglII. Transformants exhibiting the Ura<sup>+3</sup> phenotype  
10      were selected and analyzed by Southern blot hybridization. A selected transformant exhibiting the expected hybridization band pattern was designated MG18. This strain was used as a host for expression of IGF-1. The IGF-1 expressing strain was designated C+IGF816S1.

15        While the invention has been described in detail with reference to certain preferred embodiments thereof, it will be understood that modifications and variations are within the spirit and scope of that which is  
20      described and claimed.

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SEQUENCE LISTING

(1) GENERAL INFORMATION:

(i) APPLICANT: Gleeson, Martin A  
Howard, Bradley D

(ii) TITLE OF INVENTION: GENES WHICH INFLUENCE PICHIA PROTEOLYTIC  
ACTIVITY, AND USES THEREFOR

(iii) NUMBER OF SEQUENCES: 6

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(F) ZIP: 60603

(v) COMPUTER READABLE FORM:

(A) MEDIUM TYPE: Floppy disk  
(B) COMPUTER: IBM PC compatible  
(C) OPERATING SYSTEM: PC-DOS/MS-DOS  
(D) SOFTWARE: PatentIn Release #1.0, Version #1.25

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(2) INFORMATION FOR SEQ ID NO:1:

(i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 2032 base pairs  
(B) TYPE: nucleic acid

-67-

(C) STRANDEDNESS: unknown  
 (D) TOPOLOGY: unknown

(ii) MOLECULE TYPE: cDNA

(ix) FEATURE:

(A) NAME/KEY: CDS  
 (B) LOCATION: 239..1468

(ix) FEATURE:

(A) NAME/KEY: mat\_peptide  
 (B) LOCATION: 239..1468

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:1:

GAATTCTATAA	TGGTGAGATT	AGGTAAATCGT	CCGGAATAGG	AATAGTGGTT	TGGGGCGATT	60										
AATCGCACCT	GCCTTATATG	GTAAGTACCT	TGACCGATAA	GGTGGCAACT	ATTTAGAACAA	120										
AAGCAAGCCA	CCTTTCTTTA	TCTGTAACTC	TGTCGAAGCA	AGCATCTTTA	CTAGAGAACAA	180										
TCTAAACCAT	TTTACATTCT	AGAGTTCCAT	TTCTCAATTAA	CTGATAATCA	ATTTAAAG	238										
ATG	ATA	TTT	GAC	GGT	ACT	ACG	ATG	TCA	ATT	GCC	ATT	GGT	TTG	CTC	TCT	286
Met	Ile	Phe	Asp	Gly	Thr	Thr	Met	Ser	Ile	Ala	Ile	Gly	Leu	Leu	Ser	
1		5					10					15				
ACT	CTA	GGT	ATT	GGT	GCT	GAA	GCC	AAA	GTT	CAT	TCT	GCT	AAG	ATA	CAC	334
Thr	Leu	Gly	Ile	Gly	Ala	Glu	Ala	Lys	Val	His	Ser	Ala	Lys	Ile	His	
20		25										30				
AAG	CAT	CCA	GTC	TCA	GAA	ACT	TTA	AAA	GAG	GCC	AAT	TTT	GGG	CAG	TAT	382
Lys	His	Pro	Val	Ser	Glu	Thr	Leu	Lys	Glu	Ala	Asn	Phe	Gly	Gln	Tyr	
35		40										45				
GTC	TCT	GCT	CTG	GAA	CAT	AAA	TAT	GTT	TCT	CTG	TTC	AAC	GAA	CAA	AAT	430
Val	Ser	Ala	Leu	Glu	His	Lys	Tyr	Val	Ser	Leu	Phe	Asn	Glu	Gln	Asn	
50		55										60				
GCT	TTG	TCC	AAG	TCG	AAT	TTT	ATG	TCT	CAG	CAA	GAT	GGT	TTT	GCC	GTT	478
Ala	Leu	Ser	Lys	Ser	Asn	Phe	Met	Ser	Gln	Gln	Asp	Gly	Phe	Ala	Val	
65		70										75		80		
GAA	GCT	TCG	CAT	GAT	GCT	CCA	CTT	ACA	AAC	TAT	CTT	AAC	GCT	CAG	TAT	526
Glu	Ala	Ser	His	Asp	Ala	Pro	Leu	Thr	Asn	Tyr	Leu	Asn	Ala	Gln	Tyr	
85		90										95				
TTT	ACT	GAG	GTA	TCA	TTA	GGT	ACC	CCT	CCA	CAA	TCG	TTC	AAG	GTG	ATT	574
Phe	Thr	Glu	Val	Ser	Leu	Gly	Thr	Pro	Pro	Pro	Asn	Ser	Phe	Lys	Val	Ile
100		105										110				

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CTT GAC ACA GGA TCC TCC AAT TTA TGG GTT CCT AGC AAA GAT TGT GGA	622
Leu Asp Thr Gly Ser Ser Asn Leu Trp Val Pro Ser Lys Asp Cys Gly	
115 120 125	
TCA TTA GCT TGC TTC TTG CAT GCT AAG TAT GAC CAT GAT GAG TCT TCT	670
Ser Leu Ala Cys Phe Leu His Ala Lys Tyr Asp His Asp Glu Ser Ser	
130 135 140	
ACT TAT AAG AAG AAT GGT AGT AGC TTT GAA ATT AGG TAT GGA TCC GGT	718
Thr Tyr Lys Lys Asn Gly Ser Ser Phe Glu Ile Arg Tyr Gly Ser Gly	
145 150 155 160	
TCC ATG GAA GGG TAT GTT TCT CAG GAT GTG TTG CAA ATT GGG GAT TTG	766
Ser Met Glu Gly Tyr Val Ser Gln Asp Val Leu Gln Ile Gly Asp Leu	
165 170 175	
ACC ATT CCC AAA GTT GAT TTT GCT GAG GCC ACA TCG GAG CCG GGG TTG	814
Thr Ile Pro Lys Val Asp Phe Ala Glu Ala Thr Ser Glu Pro Gly Leu	
180 185 190	
GCC TTC GCT TTT GGC AAA TTT GAC GGA ATT TTG GGG CTT GCT TAT GAT	862
Ala Phe Ala Phe Gly Lys Phe Asp Gly Ile Leu Gly Leu Ala Tyr Asp	
195 200 205	
TCA ATA TCA GTA AAT AAG ATT GTT CCT CCA ATT TAC AAG GCT TTG GAA	910
Ser Ile Ser Val Asn Lys Ile Val Pro Pro Ile Tyr Lys Ala Leu Glu	
210 215 220	
TTA GAT CTC CTT GAC GAA CCA AAA TTT GCC TTC TAC TTG GGG GAT ACG	958
Leu Asp Leu Leu Asp Glu Pro Lys Phe Ala Phe Tyr Leu Gly Asp Thr	
225 230 235 240	
GAC AAA GAT GAA TCC GAT GGC GGT TTG GCC ACA TTT GGT GGT GTG GAC	1006
Asp Lys Asp Glu Ser Asp Gly Gly Leu Ala Thr Phe Gly Gly Val Asp	
245 250 255	
AAA TCT AAG TAT GAA GGA AAG ATC ACC TGG TTG CCT GTC AGA AGA AAG	1054
Lys Ser Lys Tyr Glu Gly Lys Ile Thr Trp Leu Pro Val Arg Arg Lys	
260 265 270	
GCT TAC TGG GAG GTC TCT TTT GAT GGT GTA GGT TTG GGA TCC GAA TAT	1102
Ala Tyr Trp Glu Val Ser Phe Asp Gly Val Gly Leu Gly Ser Glu Tyr	
275 280 285	
GCT GAA TTG CAA AAA ACT GGT GCA GCC ATC GAC ACT GGA ACC TCA TTG	1150
Ala Glu Leu Gln Lys Thr Gly Ala Ala Ile Asp Thr Gly Thr Ser Leu	
290 295 300	

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ATT GCT TTG CCC AGT GGC CTA GCT GAA ATT CTC AAT GCA GAA ATT GGT Ile Ala Leu Pro Ser Gly Leu Ala Glu Ile Leu Asn Ala Glu Ile Gly 305 310 315 320	1198
GCT ACC AAG GGT TGG TCT GGT CAA TAC GCT GTG GAC TGT GAC ACT AGA Ala Thr Lys Gly Trp Ser Gly Gln Tyr Ala Val Asp Cys Asp Thr Arg 325 330 335	1246
GAC TCT TTG CCA GAC TTA ACT TTA ACC TTC GCC GGT TAC AAC TTT ACC Asp Ser Leu Pro Asp Leu Thr Leu Thr Phe Ala Gly Tyr Asn Phe Thr 340 345 350	1294
ATT ACT CCA TAT GAC TAT ACT TTG GAG GTT TCT GGG TCA TGT ATT AGT Ile Thr Pro Tyr Asp Tyr Thr Leu Glu Val Ser Gly Ser Cys Ile Ser 355 360 365	1342
GCT TTC ACC CCC ATG GAC TTT CCT GAA CCA ATA GGT CCT TTG GCA ATC Ala Phe Thr Pro Met Asp Phe Pro Glu Pro Ile Gly Pro Leu Ala Ile 370 375 380	1390
ATT GGT GAC TCG TTC TTG AGA AAA TAT TAC TCA GTT TAT GAC CTA GGC Ile Gly Asp Ser Phe Leu Arg Lys Tyr Tyr Ser Val Tyr Asp Leu Gly 385 390 395 400	1438
AAA GAT GCA GTA GGT TTA GCC AAG TCT ATT TAGGCAAGAA TAAAAGTTGC Lys Asp Ala Val Gly Leu Ala Lys Ser Ile 405 410	1488
TCAGCTGAAC TTATTTGGTT ACTTATCAGG TAGTGAAGAT GTAGAGAATA TATGTTAGG TATTTTTTT TAGTTTTCT CCTATAACTC ATCTTCAGTA CGTGATTGCT TGTCAAGCTAC	1548
CTTGACAGGG GCGCATAAGT GATATCGTGT ACTGCTCAAT CAAGATTGCT CTGCTCCATT	1608
GATAAGGGTA TAAGAGACCC ACCTGCTCCT CTTAAAATT CTCTCTAAC TGTTGTGAAA	1668
ATCATCTTCG AAGCAAATTC GAGTTAAAT CTATGCGGTT GGTAACTAAA GGTATGTCAT	1728
GGTGGTATAT AGTTTTCAT TTTACCTTT ACTAATCAGT TTTACAGAAG AGGAACGTCT	1788
TTCTCAAGAT CGAAAATAGGA CTAAATACTG GAGACGATGG GGTCTTATT TGGGTGAAAG	1848
GCAGTGGGCT ACAGTAAGGG AAGACTATTC CGATGATGGA GATGCTTGGT CTGCTTTCC	1908
TTTGAGCAA TCTCATTGAA GAACTTATCG CTGGGGAGAG GATGGACTAG CTGGAGTCTC	1968
AGAC	2028
	2032

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## (2) INFORMATION FOR SEQ ID NO:2:

## (i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 410 amino acids
- (B) TYPE: amino acid
- (D) TOPOLOGY: linear

## (ii) MOLECULE TYPE: protein

## (xi) SEQUENCE DESCRIPTION: SEQ ID NO:2:

Met Ile Phe Asp Gly Thr Thr Met Ser Ile Ala Ile Gly Leu Leu Ser  
1 5 10 15

Thr Leu Gly Ile Gly Ala Glu Ala Lys Val His Ser Ala Lys Ile His  
20 25 30

Lys His Pro Val Ser Glu Thr Leu Lys Glu Ala Asn Phe Gly Gln Tyr  
35 40 45

Val Ser Ala Leu Glu His Lys Tyr Val Ser Leu Phe Asn Glu Gln Asn  
50 55 60

Ala Leu Ser Lys Ser Asn Phe Met Ser Gln Gln Asp Gly Phe Ala Val  
65 70 75 80

Glu Ala Ser His Asp Ala Pro Leu Thr Asn Tyr Leu Asn Ala Gln Tyr  
85 90 95

Phe Thr Glu Val Ser Leu Gly Thr Pro Pro Gln Ser Phe Lys Val Ile  
100 105 110

Leu Asp Thr Gly Ser Ser Asn Leu Trp Val Pro Ser Lys Asp Cys Gly  
115 120 125

Ser Leu Ala Cys Phe Leu His Ala Lys Tyr Asp His Asp Glu Ser Ser  
130 135 140

Thr Tyr Lys Lys Asn Gly Ser Ser Phe Glu Ile Arg Tyr Gly Ser Gly  
145 150 155 160

Ser Met Glu Gly Tyr Val Ser Gln Asp Val Leu Gln Ile Gly Asp Leu  
165 170 175

Thr Ile Pro Lys Val Asp Phe Ala Glu Ala Thr Ser Glu Pro Gly Leu  
180 185 190

Ala Phe Ala Phe Gly Lys Phe Asp Gly Ile Leu Gly Leu Ala Tyr Asp  
195 200 205

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Ser Ile Ser Val Asn Lys Ile Val Pro Pro Ile Tyr Lys Ala Leu Glu  
210 215 220

Leu Asp Leu Leu Asp Glu Pro Lys Phe Ala Phe Tyr Leu Gly Asp Thr  
225 230 235 240

Asp Lys Asp Glu Ser Asp Gly Gly Leu Ala Thr Phe Gly Gly Val Asp  
245 250 255

Lys Ser Lys Tyr Glu Gly Lys Ile Thr Trp Leu Pro Val Arg Arg Lys  
260 265 270

Ala Tyr Trp Glu Val Ser Phe Asp Gly Val Gly Leu Gly Ser Glu Tyr  
275 280 285

Ala Glu Leu Gln Lys Thr Gly Ala Ala Ile Asp Thr Gly Thr Ser Leu  
290 295 300

Ile Ala Leu Pro Ser Gly Leu Ala Glu Ile Leu Asn Ala Glu Ile Gly  
305 310 315 320

Ala Thr Lys Gly Trp Ser Gly Gln Tyr Ala Val Asp Cys Asp Thr Arg  
325 330 335

Asp Ser Leu Pro Asp Leu Thr Leu Thr Phe Ala Gly Tyr Asn Phe Thr  
340 345 350

Ile Thr Pro Tyr Asp Tyr Thr Leu Glu Val Ser Gly Ser Cys Ile Ser  
355 360 365

Ala Phe Thr Pro Met Asp Phe Pro Glu Pro Ile Gly Pro Leu Ala Ile  
370 375 380

Ile Gly Asp Ser Phe Leu Arg Lys Tyr Tyr Ser Val Tyr Asp Leu Gly  
385 390 395 400

Lys Asp Ala Val Gly Leu Ala Lys Ser Ile  
405 410

(2) INFORMATION FOR SEQ ID NO:3:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 2688 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: unknown
- (D) TOPOLOGY: unknown

(ii) MOLECULE TYPE: cDNA

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## (ix) FEATURE:

- (A) NAME/KEY: CDS
- (B) LOCATION: 643..1431

## (ix) FEATURE:

- (A) NAME/KEY: mat\_peptide
- (B) LOCATION: 643..1431

## (xi) SEQUENCE DESCRIPTION: SEQ ID NO:3:

CTGCAGAAAT	GGGGAGATAA	CCACCTTGA	CGAATTGACT	AAAGTTCTAC	AGATCATGTT	60										
TACAAATGCC	ATCATCTATA	ACGATGAAGA	CAGTGATGTT	TCGAAGCTAA	CGATTGAAAT	120										
GATGGAAGAA	ACTACTAAGA	TTATAGAGCT	GTTAGAGAA	AGTCTGGATT	AGTCCTGGAC	180										
AATGAACCTT	ATGTACAAAA	ATATGGGTT	AACGTCTTAG	CTGTTGCATC	ATAAGTTGGT	240										
TTTGTCTTG	GAAACGTTGA	CCAACTCTCT	CACTGTGCTT	GAGGAACCTT	TCTGCACACT	300										
TGTTGATGCA	GCCTTCCTCC	TTAGAAGTCA	ACTTGTAGA	TGTAAARTCA	TTGACACAGT	360										
CTGTAAAACA	TTTGCTAACCC	AAATCGGAGT	AAAGACGCAT	GAAGTCTTC	ATTGTTTTT	420										
GTTCAACGAG	TTTCTGGAAC	TCTTGTGTT	CTTTAGCGTT	CAATGCGTCC	ATTTGTGAT	480										
GTACTTGGTT	GGGGTAGAGT	TAGCACTTGC	TCTCTCTGTT	ACCAGTTTT	GTCAAGATTG	540										
AAGAAAAAAAG	TTTTTTGGAC	GGTACACGTC	GCACCTATCC	TTCGCATTGA	TCCACTCTAA	600										
TGAGTTAACCA	TCAACCTGAT	CAAAGGATA	GATACCTAGA	CA ATG GCT CGC AGT		654										
				Met Ala Arg Ser												
				1												
TAT	GCC	GAG	AGA	GCA	AAT	ACT	CAT	CAA	TCA	CCT	GTG	GCA	CGA	CGA	CTG	702
Tyr	Ala	Glu	Arg	Ala	Asn	Thr	His	Gln	Ser	Pro	Val	Ala	Arg	Arg	Leu	
5		10										15			20	
TTT	GCG	CTT	ATG	GAA	CAG	AAA	CAG	AGT	AAC	CTA	TGC	GCA	TCA	GTC	GAC	750
Phe	Ala	Leu	Met	Glu	Gln	Lys	Gln	Ser	Asn	Leu	Cys	Ala	Ser	Val	Asp	
25												30			35	
GTG	AGA	ACA	ACT	AAA	GAA	TTA	TTG	GAG	CTT	CTA	GAT	AAA	TTG	GGC	CCA	798
Val	Arg	Thr	Thr	Lys	Glu	Leu	Leu	Glu	Leu	Leu	Asp	Lys	Leu	Gly	Pro	
40												45			50	
TTT	ATC	TGT	TTG	GCC	AAG	ACT	CAT	ATC	GAC	ATA	ATT	GAT	GAC	TTC	ACG	846
Phe	Ile	Cys	Leu	Ala	Lys	Thr	His	Ile	Asp	Ile	Ile	Asp	Asp	Phe	Thr	
55												60			65	

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TAT GAT GGA ACT ATT CTG CCT TTA TTG GAA CTA TCA AAG AAA CAC AAG Tyr Asp Gly Thr Ile Leu Pro Leu Leu Glu Leu Ser Lys Lys His Lys 70 75 80	894
TTT TTA ATT TTT GAG GAC AGA AAG TTT GCT GAT ATA GGC AAC ACT GTC Phe Leu Ile Phe Glu Asp Arg Lys Phe Ala Asp Ile Gly Asn Thr Val 85 90 95 100	942
AAG CAT CAA TAT CAA GGA GGT GTC TAC AAG ATT GCA CAA TGG GCA GAT Lys His Gln Tyr Gln Gly Gly Val Tyr Lys Ile Ala Gln Trp Ala Asp 105 110 115	990
ATT ACA AAT GCT CAT GGT GTC ATT GGT AGT GGA ATT GTA AAG GGT CTA Ile Thr Asn Ala His Gly Val Ile Gly Ser Gly Ile Val Lys Gly Leu 120 125 130	1038
AAG GAG GCA GCC ACT GAG ACA ACA GAT CAA CCA AGG GGA CTA TTG ATG Lys Glu Ala Ala Thr Glu Thr Thr Asp Gln Pro Arg Gly Leu Leu Met 135 140 145	1086
TTG GCT GAA CTG TCG TCA AAG GGA TCA ATT GCC CAT GGT AAG TAC ACC Leu Ala Glu Leu Ser Ser Lys Gly Ser Ile Ala His Gly Lys Tyr Thr 150 155 160	1134
GAA GAA ACT GTA GAA ATT GCA AAA TCA GAC AAG GAA TTC GTC ATT GGG Glu Glu Thr Val Glu Ile Ala Lys Ser Asp Lys Glu Phe Val Ile Gly 165 170 175 180	1182
TTT ATT GCT CAA AAT TCT ATG GGA GGA CAA GAT GAA GGG TTC GAT TGG Phe Ile Ala Gln Asn Ser Met Gly Gly Gln Asp Glu Gly Phe Asp Trp 185 190 195	1230
ATT ATT ATG ACA CCA GGT GTT GGT TTG GAT GAC ACT GGT GAT GCT CTA Ile Ile Met Thr Pro Gly Val Gly Leu Asp Asp Thr Gly Asp Ala Leu 200 205 210	1278
GGC CAA CAA TAT CGA ACA GTG AGT CAA GTA TTT TCC ACT GGC ACT GAC Gly Gln Gln Tyr Arg Thr Val Ser Gln Val Phe Ser Thr Gly Thr Asp 215 220 225	1326
ATC ATA ATC GTA GGT CGT GGT TTG TTT GGC AAG GGC AGA GAT CCC TTA Ile Ile Ile Val Gly Arg Gly Leu Phe Gly Lys Gly Arg Asp Pro Leu 230 235 240	1374
AAA GAA GGT GAA CGG TAT AGA AAA GCT GGG TGG GAA GCT TAC CAA AAT Lys Glu Gly Glu Arg Tyr Arg Lys Ala Gly Trp Glu Ala Tyr Gln Asn 245 250 255 260	1422
ATT CTG AGG TAAATTACAA GTATGTACAG GGGATCAATT GTTTGGGGCG Ile Leu Arg	1471

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ATTCAACTGA ATCGATCTTC AATTCATCG CTCATTTC GACGCAGTAT TTCAAAACACC	1531
AGAAGCCCCA CGGATGTTGC TGGAATGGTA GTAAACGCAT TCCTAACGAA CCCTTTATAA	1591
AACCAGCGGG TCCAAGATAG TTTAGACTTC TCATGTAAGC TCACCAACTG GTGGAATGTA	1651
TCTAAGTATG ATCGGTAATA TAGACGGAAT TTACTTTCT TATCCCAGGA GTTCTCGTTG	1711
AAAATATCCA ACGCTTCCAA CCTTGCTAAA TGTATTGACT GAACTTTAGA AAATGGGTAT	1771
TGAACGGCTA GTAACGAACA TGCAGCGCTA GCACCAAGCCA AAAGAATAAA AGTCGTCCCTC	1831
AGGATATTT CACTTTTCGT TTTCACTGTG TCACCTTGGG GCCTTCCAAG AAGACTATTT	1891
TTCATCCTAT CAATTCTCTC CATACTGTTTC TCGGTTATCC TGTAACCTCT ATTCTTAATG	1951
GCTTCGAATG TTGTGAAATA TATAGCAAAG GATGTGCTTT CTTTGACCAAG ACTCAAGGAG	2011
TAGCCAGCAA ATACCCCCAG AAAACCACTA GTTTTAGTT TATGAAGACC GTAAATCCAT	2071
AAGTTGTCAT TCTTGCCCCC AATAATCTCG GAGGCATTAG ATCGGGCATA TATTGCATCA	2131
ATTGGGGCAG CTACCAATGA CTGGCGAGCT CCAGCTAGAA ACCCAGCTCG AAATACATCC	2191
ACTAGTCTTG GATTTGCTAT CGATCTGCC CTTTGACCGT CAGTATATGA CTGCAAACAT	2251
GATAAAATACG TTGTGAAAG TACAATTCCC ATCACAGAAAT TGGCTACCAA TGGTGGCAGG	2311
ACCTTGTTC GTATCAAATC CCAACCAGG GTTTGACGG CTCGTAACAA TAGAGCTGGA	2371
TTTGAGTGGAA AAATGGGCTG TAAGGTTAC CTTCAATG AGCTCAAAG AAGATGCGTA	2431
TTGGTGCAT GTAGTCAAAA CGAGTGGGAC GAAACAGTTT GGCTGGTGTG CTCAGGTACA	2491
GTGAACTAAA TTGGACTAGA ACAGCTCTGA TCCCAGCTGT CGAAGCAGAC ACCACTTGAG	2551
TGTTTTGTT GCTAAGAGTA GCCTTTAG AATCATCGTT GTCTTCCATA CGTTTCTGGA	2611
ACACAATGCC AGAGTTCATA GAGGATCAGA GGGGAATTGA GGTGTGTGTA TATGTATTTA	2671
TAGGGGTACCG GAGCTCG	2688

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(2) INFORMATION FOR SEQ ID NO:4:

(i) SEQUENCE CHARACTERISTICS:  
(A) LENGTH: 263 amino acids  
(B) TYPE: amino acid  
(D) TOPOLOGY: linear

(ii) MOLECULE TYPE: protein

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:4:

Met Ala Arg Ser Tyr Ala Glu Arg Ala Asn Thr His Gln Ser Pro Val  
1 5 10 15

Ala Arg Arg Leu Phe Ala Leu Met Glu Gln Lys Gln Ser Asn Leu Cys  
20 25 30

Ala Ser Val Asp Val Arg Thr Thr Lys Glu Leu Leu Glu Leu Leu Asp  
35 40 45

Lys Leu Gly Pro Phe Ile Cys Leu Ala Lys Thr His Ile Asp Ile Ile  
50 55 60

Asp Asp Phe Thr Tyr Asp Gly Thr Ile Leu Pro Leu Leu Glu Leu Ser  
65 70 75 80

Lys Lys His Lys Phe Leu Ile Phe Glu Asp Arg Lys Phe Ala Asp Ile  
85 90 95

Gly Asn Thr Val Lys His Gln Tyr Gln Gly Gly Val Tyr Lys Ile Ala  
100 105 110

Gln Trp Ala Asp Ile Thr Asn Ala His Gly Val Ile Gly Ser Gly Ile  
115 120 125

Val Lys Gly Leu Lys Glu Ala Ala Thr Glu Thr Thr Asp Gln Pro Arg  
130 135 140

Gly Leu Leu Met Leu Ala Glu Leu Ser Ser Lys Gly Ser Ile Ala His  
145 150 155 160

Gly Lys Tyr Thr Glu Glu Thr Val Glu Ile Ala Lys Ser Asp Lys Glu  
165 170 175

Phe Val Ile Gly Phe Ile Ala Gln Asn Ser Met Gly Gly Gln Asp Glu  
180 185 190

Gly Phe Asp Trp Ile Ile Met Thr Pro Gly Val Gly Leu Asp Asp Thr  
195 200 205

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Gly Asp Ala Leu Gly Gln Gln Tyr Arg Thr Val Ser Gln Val Val Phe Ser  
 210 215 220

Thr Gly Thr Asp Ile Ile Ile Val Gly Arg Gly Leu Phe Gly Lys Gly  
 225 230 235 240

Arg Asp Pro Leu Lys Glu Gly Glu Arg Tyr Arg Lys Ala Gly Trp Glu  
 245 250 255

Ala Tyr Gln Asn Ile Leu Arg  
 260

## (2) INFORMATION FOR SEQ ID NO:5:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 555 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: unknown
- (D) TOPOLOGY: unknown

(ii) MOLECULE TYPE: cDNA

(ix) FEATURE:

- (A) NAME/KEY: CDS
- (B) LOCATION: 3..554

(ix) FEATURE:

- (A) NAME/KEY: mat\_peptide
- (B) LOCATION: 3..554

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:5:

GA ATT CTG CAG GGA AAC GGC CAC GGT ACA CAT TGT GCT GGT ACC ATT Ile Leu Gln Gly Asn Gly His Gly Thr His Cys Ala Gly Thr Ile	47
1 5 10 15	
GCT TCT GAA AGC TAC GGT GTT GCC AAG AAG GCT AAT GTT GTT GCC ATC Ala Ser Glu Ser Tyr Gly Val Ala Lys Lys Ala Asn Val Val Ala Ile	95
20 25 30	
AAG GTC TTG AGA TCT AAT GGT TCT GGT TCG ATG TCA GAT GTT CTG AAG Lys Val Leu Arg Ser Asn Gly Ser Gly Ser Met Ser Asp Val Leu Lys	143
35 40 45	
GGT GTT GAG TAT GCC ACC CAA TCC CAC TTG GAT GCT GTT AAA AAG GGC Gly Val Glu Tyr Ala Thr Gln Ser His Leu Asp Ala Val Lys Lys Gly	191
50 55 60	

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AAC AAG AAA TTT AAG GGC TCT ACC GCT AAC ATG TCA CTG GGT GGT	239
Asn Lys Lys Phe Lys Gly Ser Thr Ala Asn Met Ser Leu Gly Gly Gly	
65 70 75	
AAA TCT CCT GCT TTG GAC CTT GCA GTC AAT GCT GCT GTT AAG AAT GGT	287
Lys Ser Pro Ala Leu Asp Leu Ala Val Asn Ala Ala Val Lys Asn Gly	
80 85 90 95	
ATT CAC TTT GCC GTT GCA GCA GGT AAC GAA AAC CAA GAT GCT TGT AAC	335
Ile His Phe Ala Val Ala Ala Gly Asn Glu Asn Gln Asp Ala Cys Asn	
100 105 110	
ACC TCG CCA GCA GCT GCT GAG AAT GCC ATC ACC GTC GGT GCA TCA ACC	383
Thr Ser Pro Ala Ala Ala Glu Asn Ala Ile Thr Val Gly Ala Ser Thr	
115 120 125	
TTA TCA GAC GCT AGA GCT TAC TTT TCT AAC TAC GGT AAA TGT GTT GAC	431
Leu Ser Asp Ala Arg Ala Tyr Phe Ser Asn Tyr Gly Lys Cys Val Asp	
130 135 140	
ATT TTC GCT CCA GGT TTA AAC ATT CTT TCT ACC TAC ACT GGT TCG GAT	479
Ile Phe Ala Pro Gly Leu Asn Ile Leu Ser Thr Tyr Thr Gly Ser Asp	
145 150 155	
GAC GCA ACT GCT ACC TTG TCT GGT ACT TCA ATG GCC AGC CCT CAT GTT	527
Asp Ala Thr Ala Thr Leu Ser Gly Thr Ser Met Ala Ser Pro His Val	
160 165 170 175	
GCA GGC TTG CAT GCA AGC TTG GCA CTG G	555
Ala Gly Leu His Ala Ser Leu Ala Leu	
180	

## (2) INFORMATION FOR SEQ ID NO:6:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 184 amino acids
- (B) TYPE: amino acid
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: protein

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:6:

Ile Leu Gln Gly Asn Gly His Gly Thr His Cys Ala Gly Thr Ile Ala	
1 5 10 15	
Ser Glu Ser Tyr Gly Val Ala Lys Lys Ala Asn Val Val Ala Ile Lys	
20 25 30	

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Val Leu Arg Ser Asn Gly Ser Gly Ser Met Ser Asp Val Leu Lys Gly  
35 40 45

Val Glu Tyr Ala Thr Gln Ser His Leu Asp Ala Val Lys Lys Gly Asn  
50 55 60

Lys Lys Phe Lys Gly Ser Thr Ala Asn Met Ser Leu Gly Gly Lys  
65 70 75 80

Ser Pro Ala Leu Asp Leu Ala Val Asn Ala Ala Val Lys Asn Gly Ile  
85 90 95

His Phe Ala Val Ala Ala Gly Asn Glu Asn Gln Asp Ala Cys Asn Thr  
100 105 110

Ser Pro Ala Ala Ala Glu Asn Ala Ile Thr Val Gly Ala Ser Thr Leu  
115 120 125

Ser Asp Ala Arg Ala Tyr Phe Ser Asn Tyr Gly Lys Cys Val Asp Ile  
130 135 140

Phe Ala Pro Gly Leu Asn Ile Leu Ser Thr Tyr Thr Gly Ser Asp Asp  
145 150 155 160

Ala Thr Ala Thr Leu Ser Gly Thr Ser Met Ala Ser Pro His Val Ala  
165 170 175

Gly Leu His Ala Ser Leu Ala Leu  
180

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**THAT WHICH IS CLAIMED IS:**

1. An isolated DNA fragment obtained from a strain of the genus *Pichia*, comprising a gene encoding a protein which, directly or indirectly, influences the proteolytic activity of said strain.  
5
2. The DNA fragment of Claim 1, wherein said protein influences the carboxypeptidase Y activity of  
10 said strain.
3. The DNA fragment of Claim 2, wherein said gene has the restriction map in FIG. 1 of the drawings.
- 15 4. The DNA fragment of Claim 2, wherein said fragment is the approximately 10.6 kbp EcoRI fragment of plasmid pEP202.
- 20 5. The DNA fragment of Claim 2, wherein said fragment is the approximately 2.7 kbp EcoRI-SacI fragment of plasmid pEP301, or portions thereof that encode a protein which influences the carboxypeptidase Y activity of said strain.
- 25 6. The DNA fragment of Claim 2, wherein said the nucleic acid sequence of said gene encodes an amino acid sequence which is substantially the same as the amino acid sequence set forth in Sequence ID No. 2.
- 30 7. The DNA fragment of Claim 2, wherein the nucleic acid sequence of said gene is substantially the same as the nucleic acid sequence set forth in Sequence ID No. 1.

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8. An isolated DNA fragment containing a modified form of the gene of Claim 1, wherein said modification renders the gene incapable of producing functional product, or alters the ability of the gene product to 5 influence the proteolytic activity of said strain.

9. The DNA fragment of Claim 8, wherein the modified form of said gene is suitable for introduction into a yeast host of the genus *Pichia* by homologous 10 recombination, wherein homologous recombination occurs at the specific locus of said gene whose expression product influences proteolytic activity.

10. The DNA fragment of Claim 8, wherein the modified gene, in its unmodified form, encodes a protein 15 that influences the carboxypeptidase Y activity of said strain.

11. The DNA fragment of Claim 9, wherein said gene 20 is modified by the insertion of an auxotrophic marker gene therein.

12. A DNA fragment of Claim 11, wherein said auxotrophic marker gene is selected from the *Pichia* or 25 *Saccharomyces HIS4* gene, the *Pichia* or *Saccharomyces ARG4* gene, or the *Pichia* or *Saccharomyces URA3* gene.

13. The DNA fragment of Claim 12, wherein said fragment is included in plasmid pDR401.

30

14. The DNA fragment of Claim 9, wherein said gene is modified by making deletions therefrom.

15. The DNA fragment of Claim 14, wherein said 35 fragment is included in plasmid pDR421.

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16. A method of producing strain(s) of the genus *Pichia* which are deficient in proteolytic activity, compared to host strain(s) of the same species, comprising:

5        contacting said host strain(s) with the DNA fragment of Claim 8 under conditions suitable for the site-directed integration of said DNA fragment into the genome of said host strain(s), wherein said site-directed integration occurs at the specific locus of said gene  
10      which encodes a protein which influences proteolytic activity.

17. The method of Claim 16, further comprising:  
screening the strains obtained as a result of said  
15      contacting for the presence of strains which have reduced proteolytic activity, relative to said host strain(s), and  
selecting those strains which have reduced proteolytic activity, relative to said host strain(s).

20      18. The method of Claim 16, wherein integration of said DNA fragment influences the proteinase A and carboxypeptidase Y activities of said host organism.

25      19. A strain of *Pichia* deficient in proteolytic activity produced by the method of Claim 16.

20      20. The strain of Claim 19, which is deficient in proteinase A and carboxypeptidase Y activities.

30      21. The strain of Claim 20 selected from *P. pastoris* strain p1, p2, p5, p8, p13, p16, or p20.

35      22. The method of Claim 16, wherein said host strain is defective in at least one auxotrophic marker

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gene selected from the histidinol dehydrogenase gene, the argininosuccinate lyase gene, or the orotidine-5'-phosphate decarboxylase gene, and wherein the modified gene of said fragment is modified by the insertion  
5 therein of an intact form of the auxotrophic marker gene in which the host strain is defective.

23. A strain of *Pichia* deficient in proteolytic activity produced by the method of Claim 22.

10

24. A strain of Claim 23, wherein said strain is deficient in proteinase A and carboxypeptidase Y activity.

15

25. A strain of Claim 24 selected from *P. pastoris* strain p1, p2, p5, p8, p13, p16, or p20.

26. The method of Claim 16, wherein the gene said fragment is modified by making deletions therefrom.

20

27. The method of Claim 22, wherein said host strain is GS115 and said DNA fragment is the approximately 5.3 kbp SacI-EcoRI fragment of plasmid pDR401.

25

28. A yeast cell of the genus *Pichia* which is deficient in proteolytic activity, compared to wild-type strains of the same species.

30

29. The yeast cell of Claim 28, wherein said cell is deficient in proteinase A and carboxypeptidase Y activities.

35

30. A method for the expression of proteolytically sensitive recombinant product(s), comprising:

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transforming the cell of Claim 28 with DNA encoding said product and culturing said cell under conditions whereby said proteolytically sensitive product(s) is expressed.

5        31. The method of claim 30, wherein the cell is rendered deficient in proteolytic activity by replacement of a gene of the cell that encodes a protein which, upon expression, directly or indirectly, influences the carboxypeptidase Y activity of said host organism with a 10 defective form of said gene modified by the insertion therein of a marker gene which complements an auxotrophic phenotype of said host strain; and wherein the marker gene is selected from the histidinol dehydrogenase gene, the argininosuccinate lyase gene, or the 15 orotidine-5'-phosphate decarboxylase gene.

32. A method for the expression of proteolytically sensitive recombinant product(s), comprising rendering a host strain deficient in proteolytic 20 activity using the method of Claim 16, wherein said host strain is defective in at least one auxotrophic marker gene; and said host strain has been transformed with at least one DNA fragment comprising an expression cassette 25 comprising, in the reading frame direction of transcription, the following sequences of nucleotides:  
(i) a promoter region of a methanol-responsive gene of a methylotrophic yeast,  
(ii) a sequence encoding a polypeptide consisting 30 essentially of:  
(a) an optional secretion signal sequence, and  
(b) a proteolytically sensitive protein; and  
(iii) a transcription terminator functional in a methylotrophic yeast;

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wherein said sequences are operationally associated with one another for transcription of the sequences encoding said polypeptide.

5       33. The method of Claim 32, wherein said host strain is defective in at least two auxotrophic marker genes.

10      34. A method of Claim 33, wherein said auxotrophic marker genes are the *HIS4* gene, and the *URA3* gene.

15      35. A method of Claim 34, wherein the proteolytically sensitive product is IGF-1 and the marker gene employed for transforming said host with DNA encoding IGF-1 is the *HIS4* gene.

20      36. A method of Claim 35, wherein the modified gene employed to render the host deficient in proteolytic activity, in its unmodified form, encodes a protein that influences the carboxypeptidase activity of the host.

25      37. A method of Claim 36, wherein the modified gene is produced by deletion of a portion of the coding sequence therefrom.

38. A method of Claim 37, wherein the recombinant strain from which said recombinant product(s) is expressed is strain M+IMB206S1.

30      39. An isolated DNA fragment, comprising the orotidine-5'-phosphate decarboxylase gene from species of the genus *Pichia*.

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40. The DNA fragment of Claim 39, wherein said gene has substantially the same restriction map as shown in FIG. 12.

5 41. The DNA fragment of Claim 39, wherein said gene encodes substantially the same amino acid sequence as set forth in Sequence ID No. 4.

10 42. A DNA fragment of Claim 39, wherein said gene has substantially the same nucleic acid sequence as set forth in Sequence ID No. 3.

15 43. A yeast cell of the genus *Pichia*, which is defective in the orotidine-5'-phosphate decarboxylase gene.

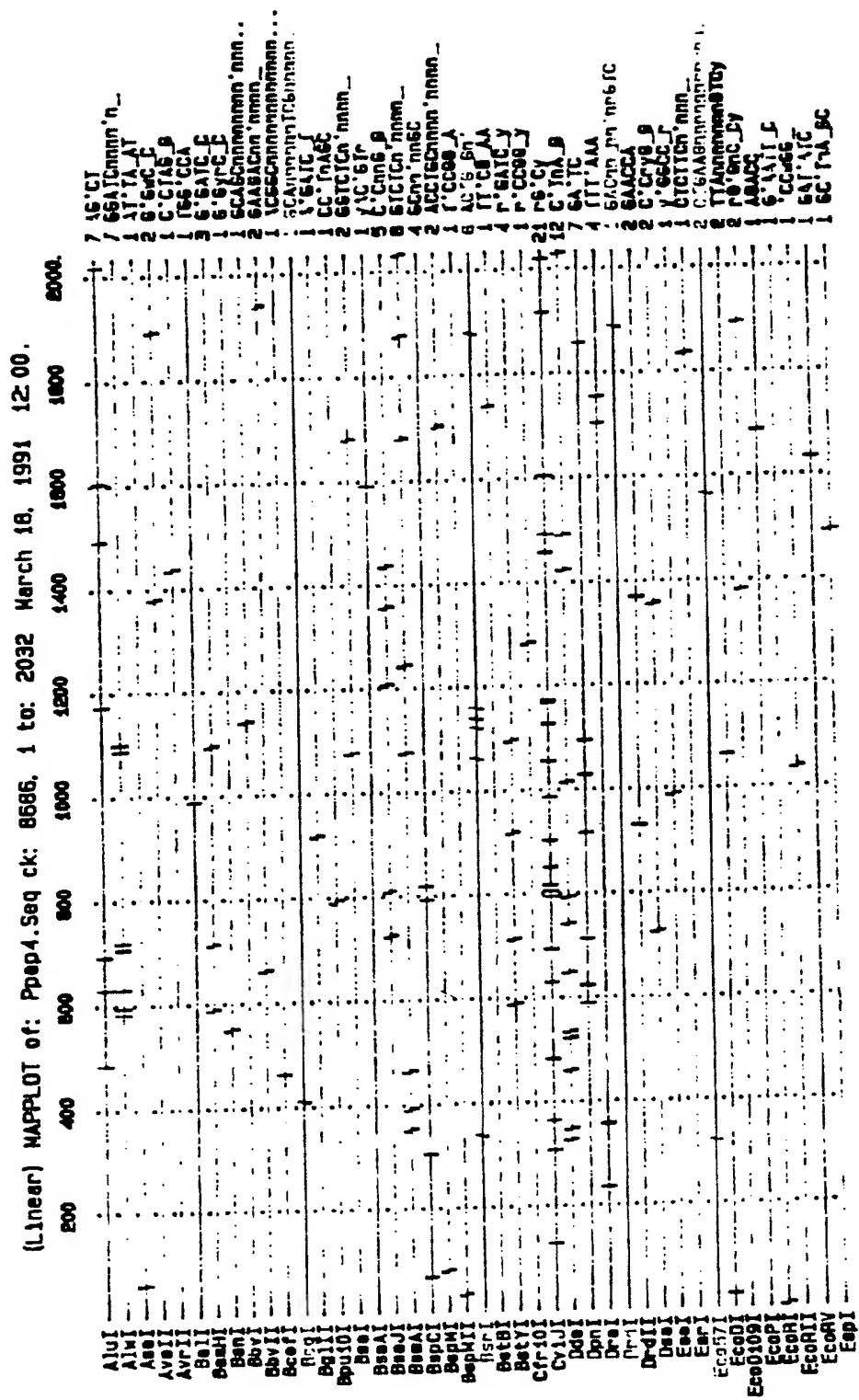
44. The yeast cell of Claim 43, wherein said yeast cell is a strain of *Pichia pastoris*.

20 45. The yeast cell of Claim 44, wherein said yeast cell is the strain *Pichia pastoris* GS4-2.

46. The yeast cell of Claim 43, further containing a deficiency in proteolytic activity.

25 47. A yeast cell of Claim 46, wherein said yeast cell is deficient in proteinase A and carboxypeptidase Y activities.

30 48. The yeast cell of Claim 47, wherein said yeast cell is selected from the *Pichia pastoris* strains GS4-2521-3/7 or GS4-2521-4/1.



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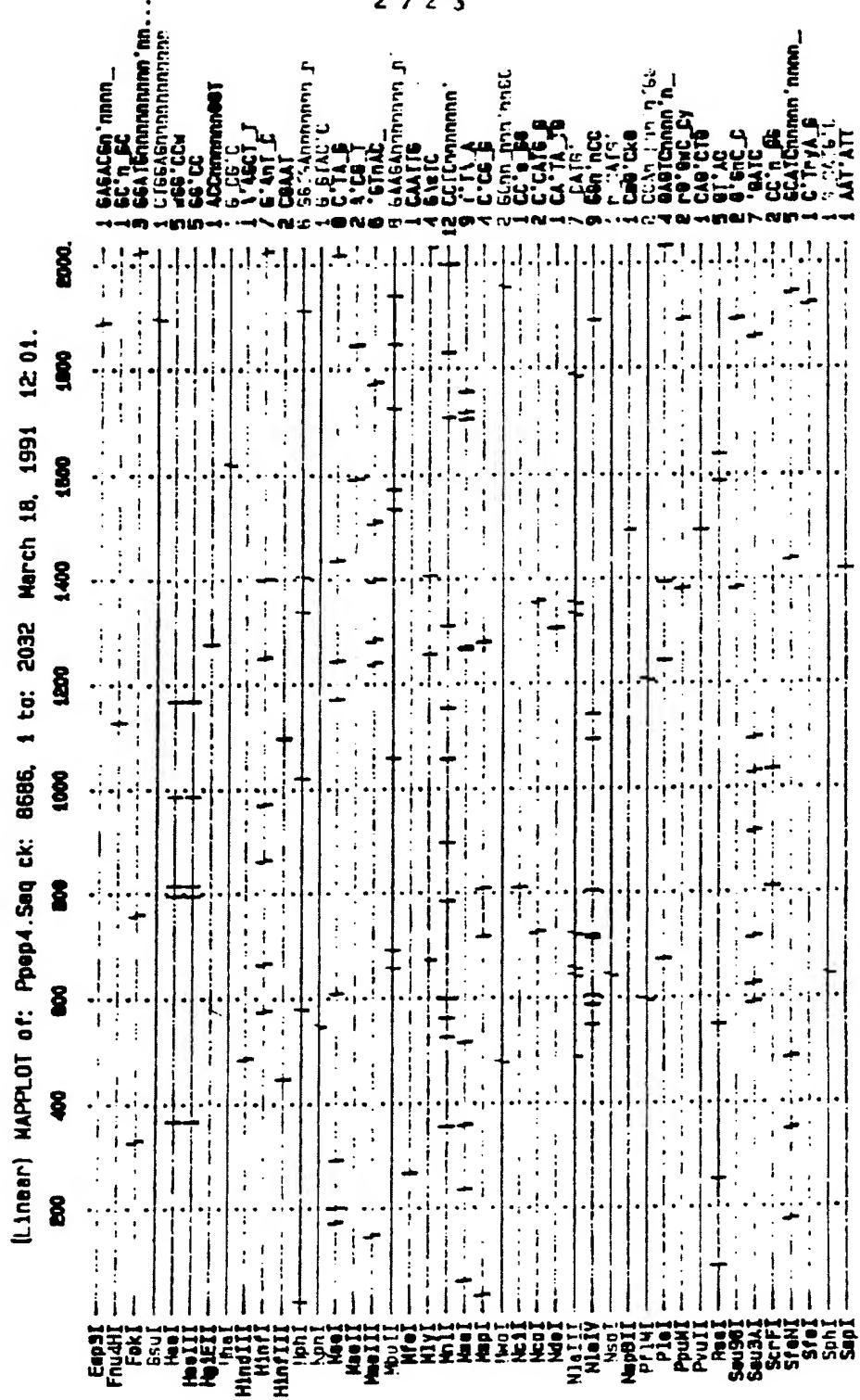


FIG. 1-2

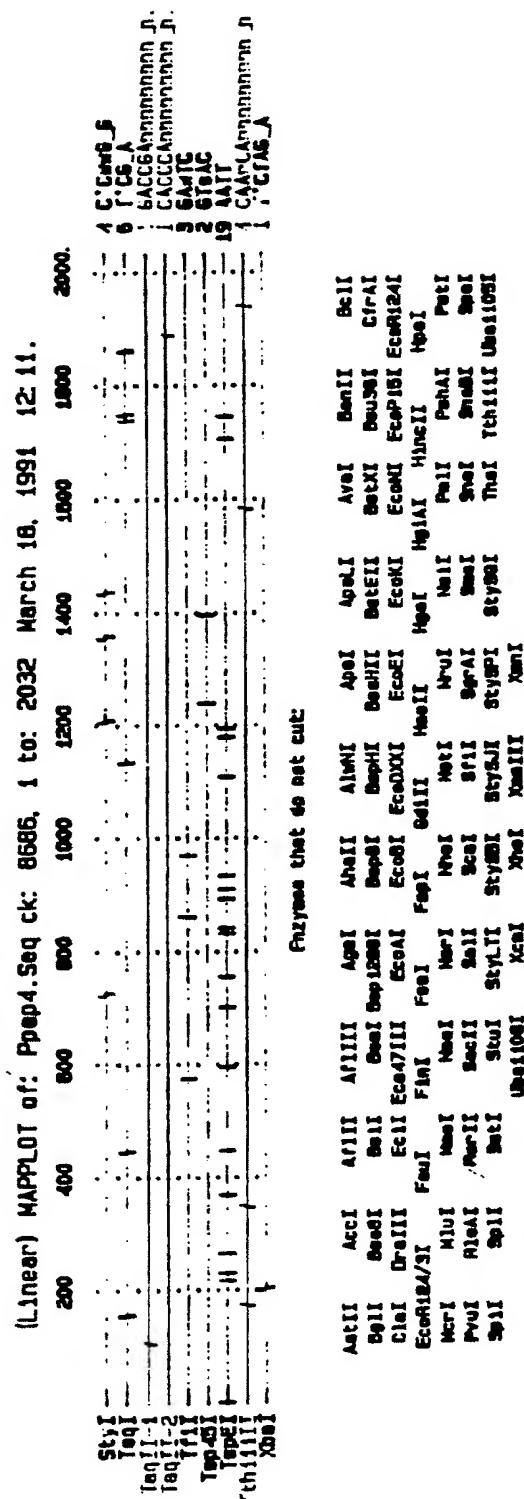


FIG -3

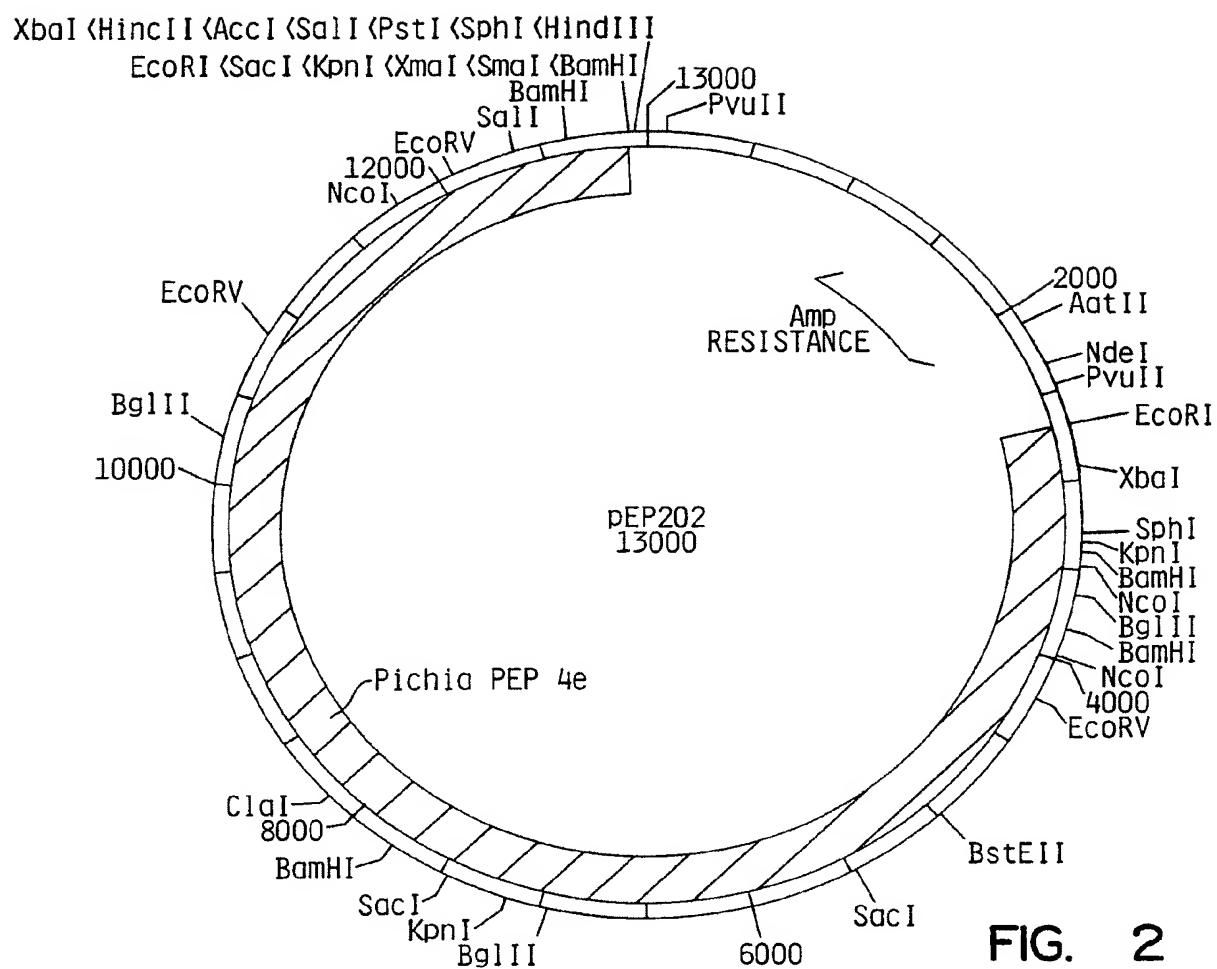
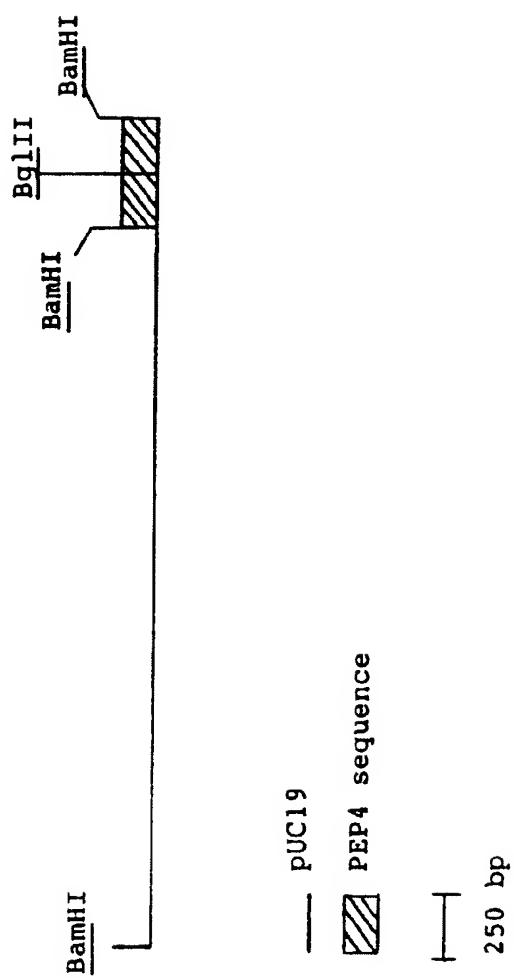


FIG. 2

5 / 2 3

FIGURE 3  
Linear Restriction Map of pEP205



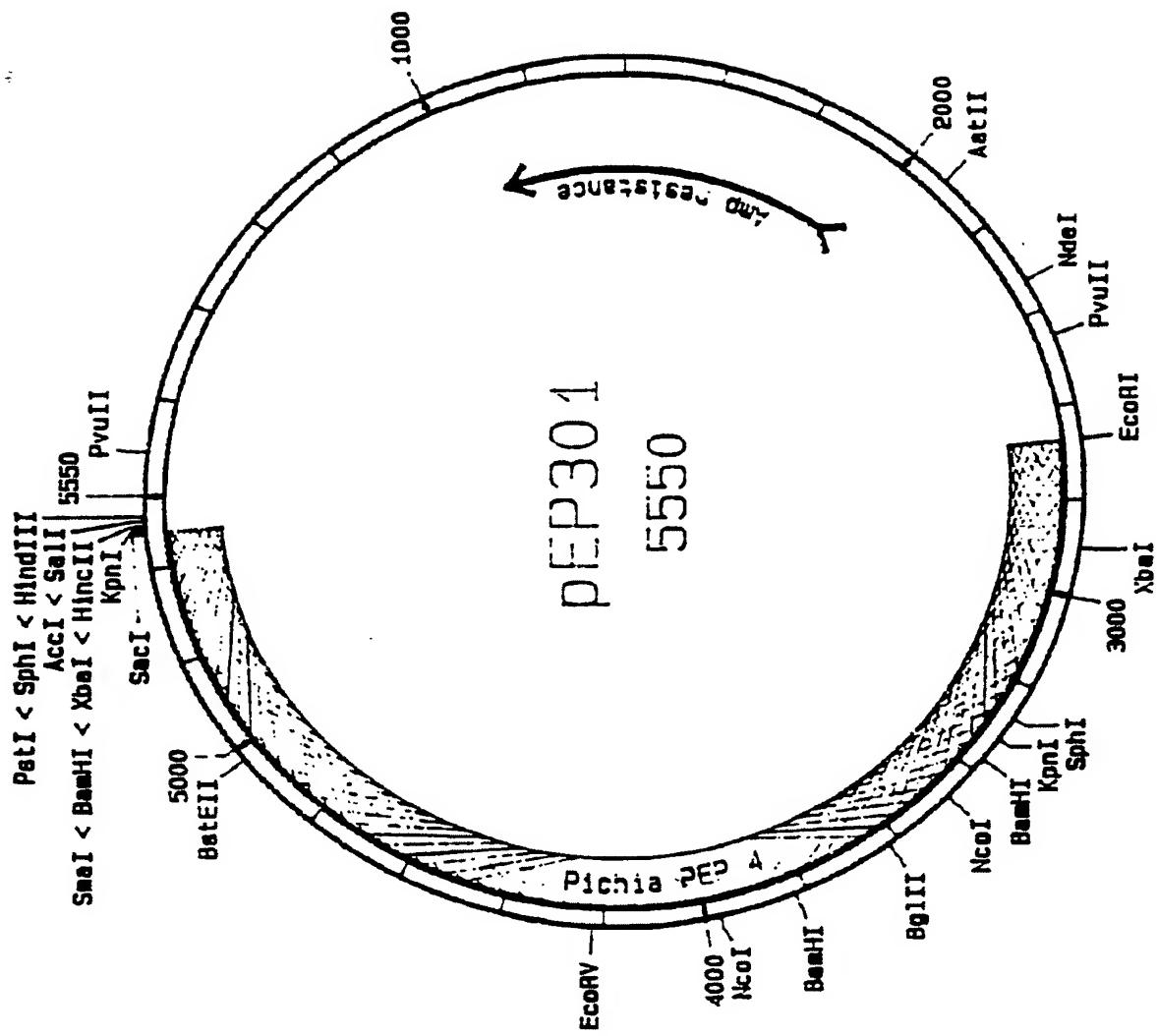


Fig  
4

- 7 / 2 3

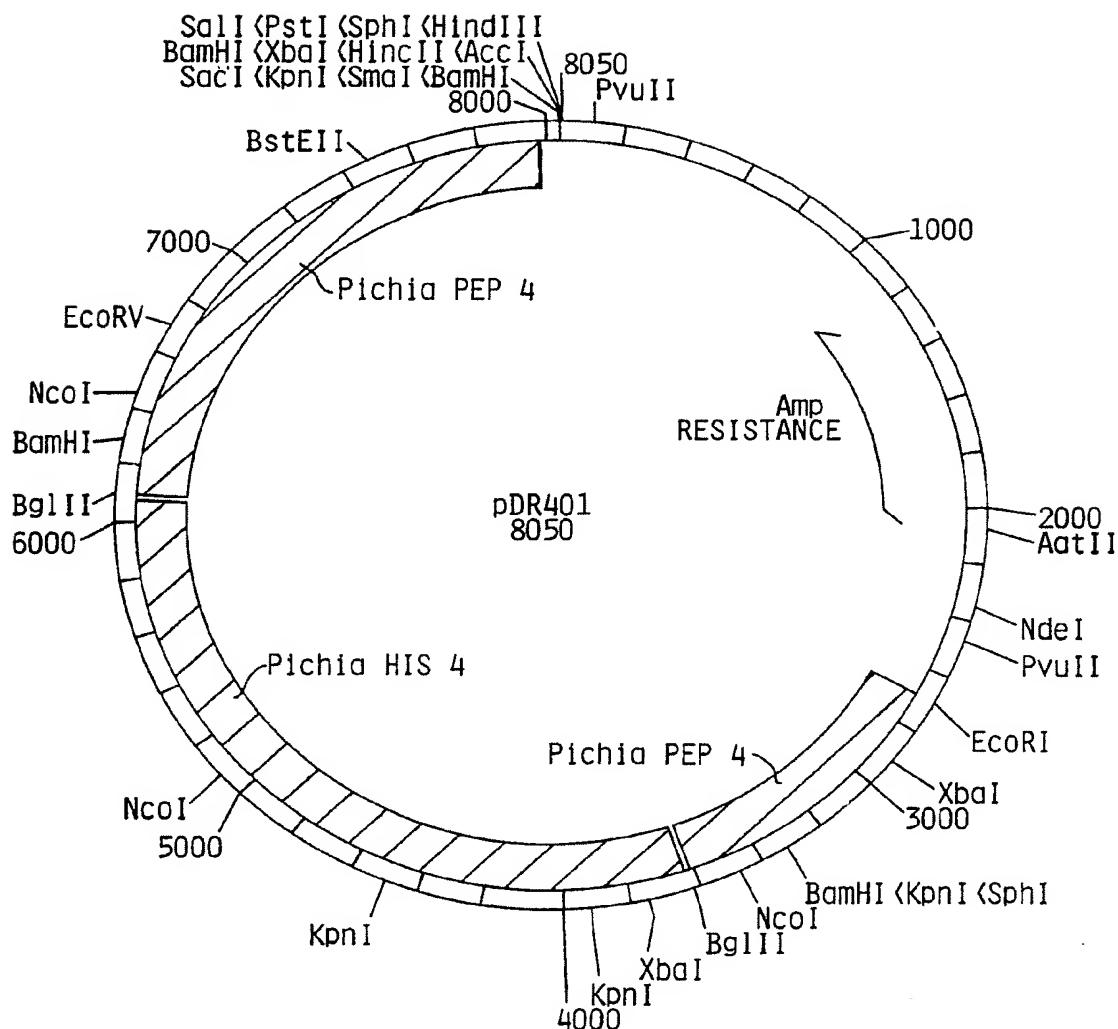


FIG. 5

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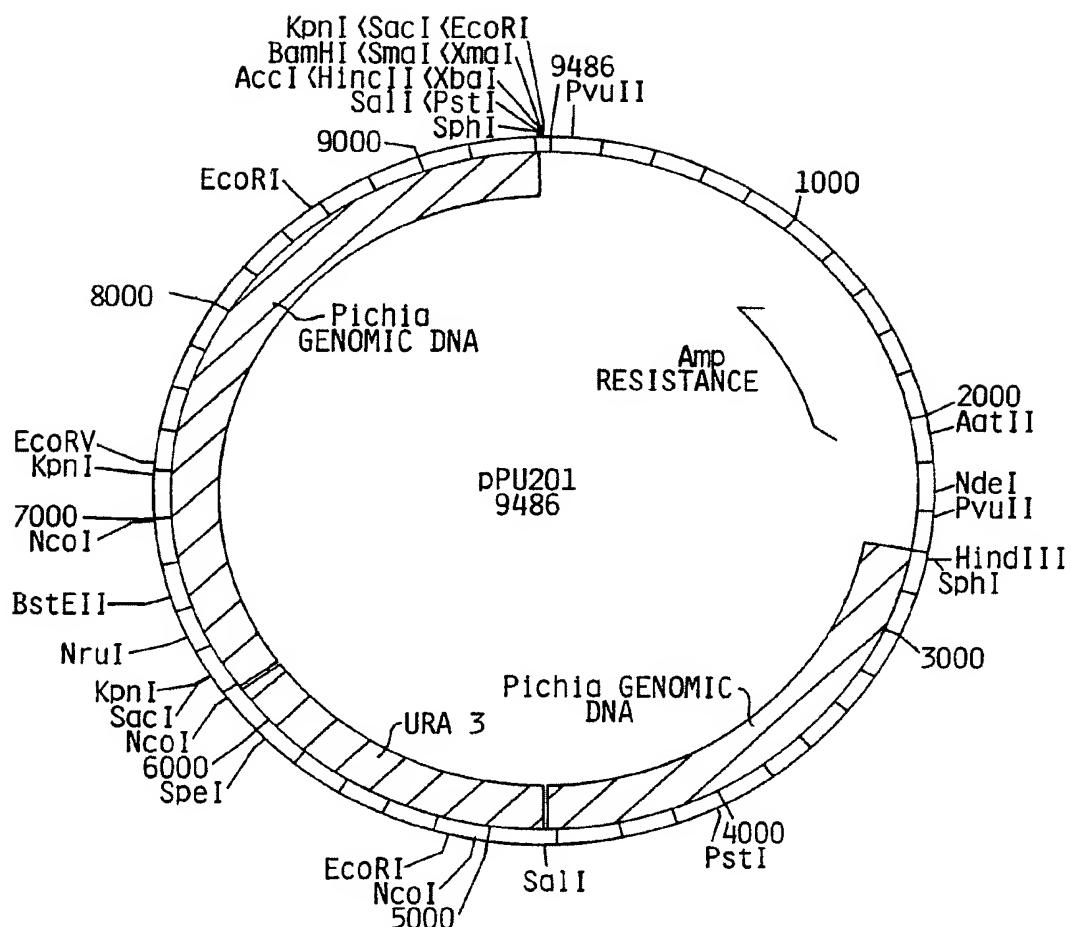
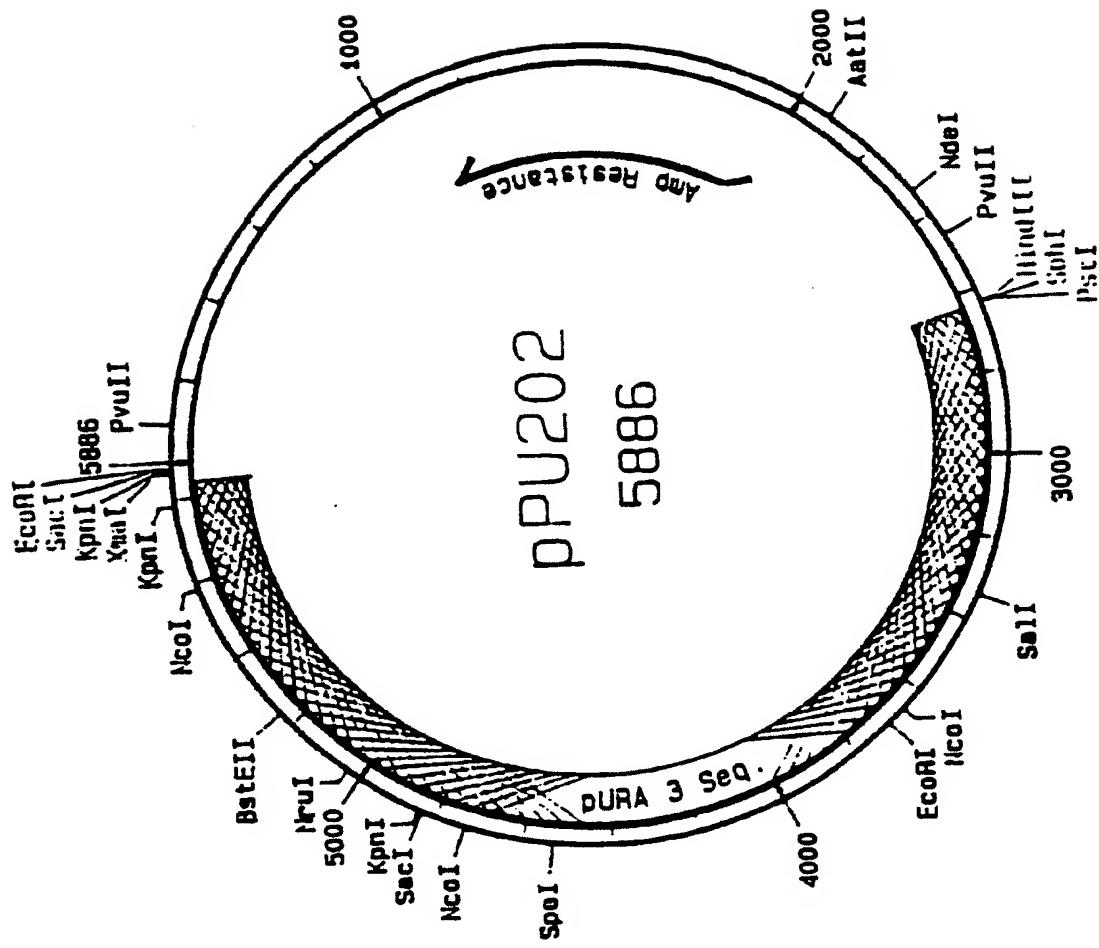


FIG. 6

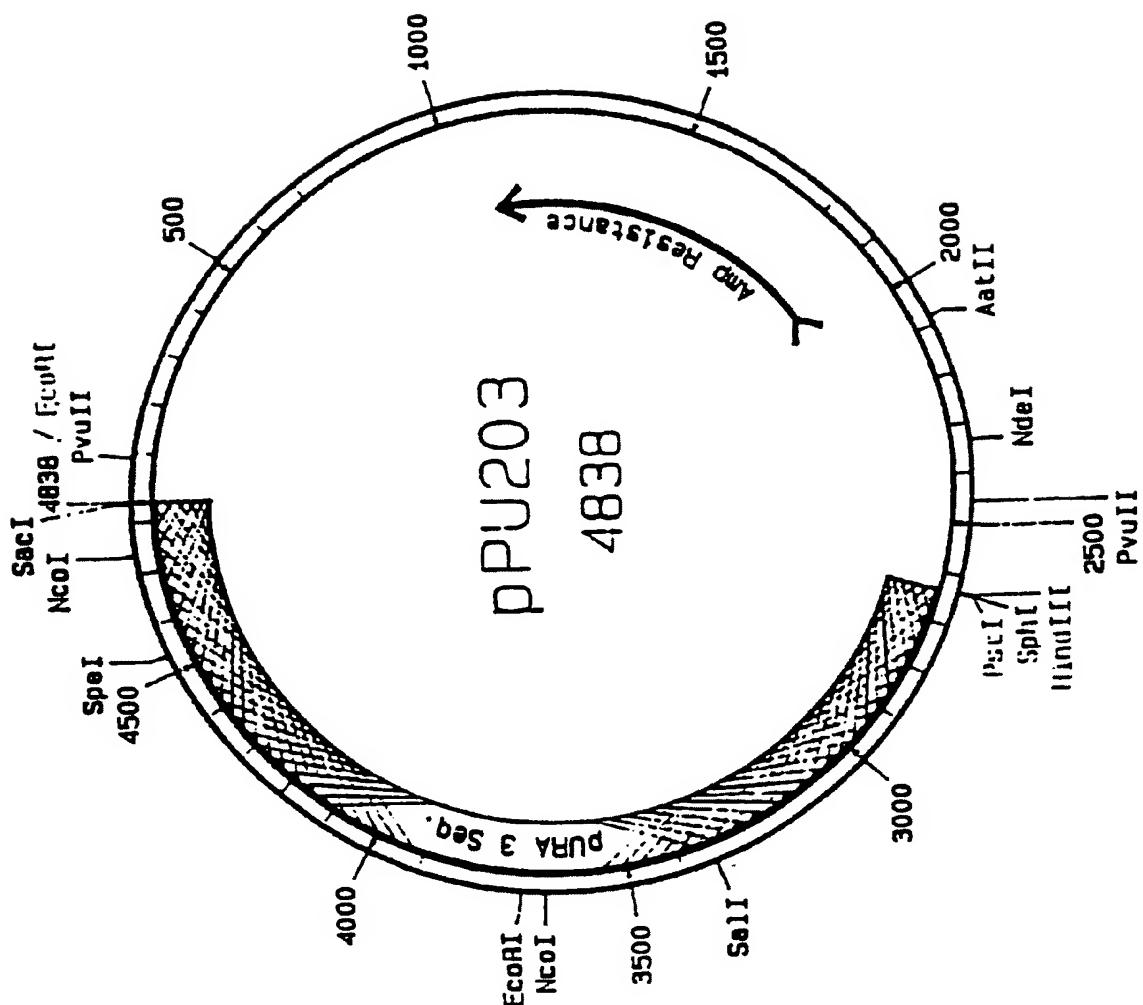
SUBSTITUTE SHEET

FIG 7



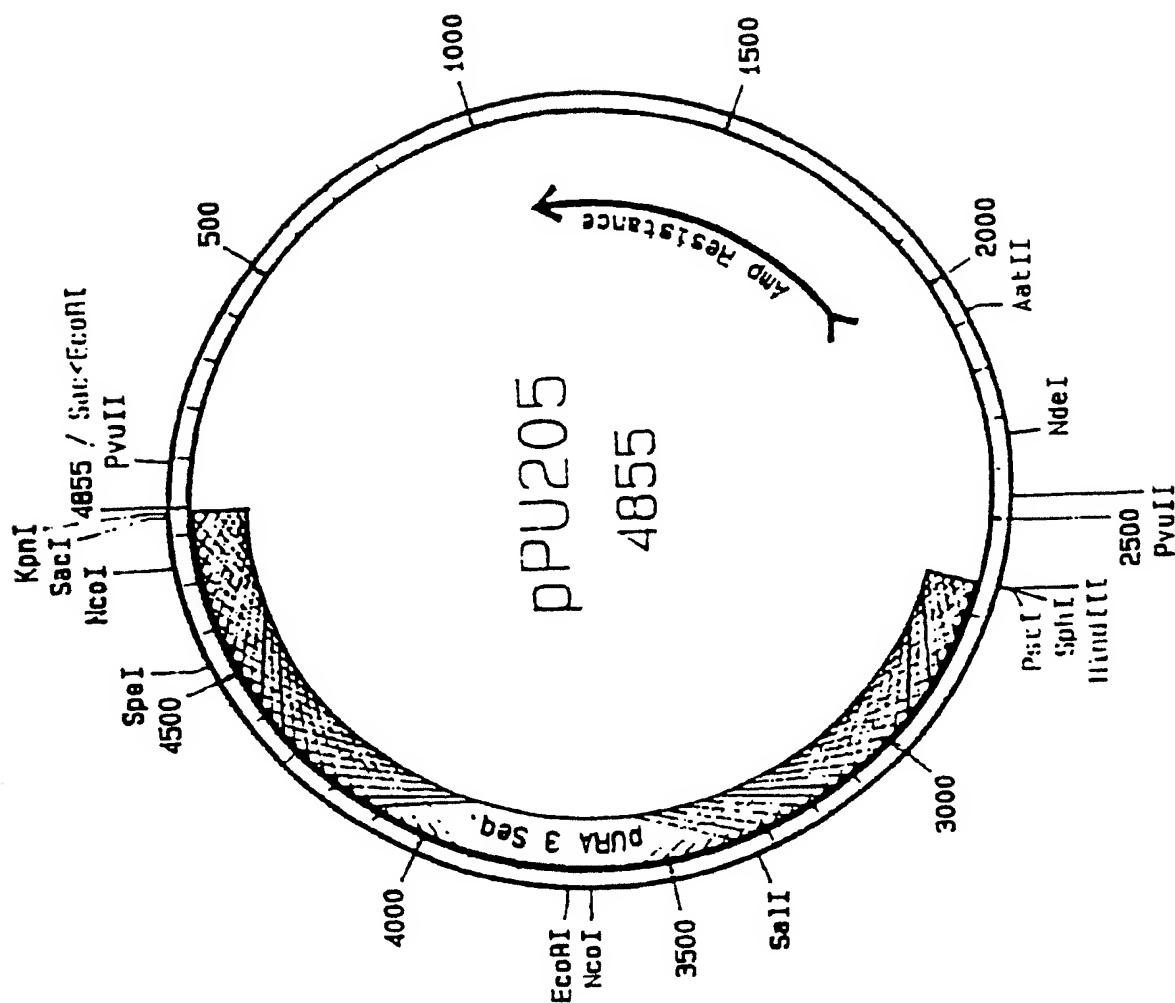
PLASMIDMAP of: pPU202.Seq check: 5464 from: 1 to: 5886

Howard April 4, 1990 08:59

FIG  
8

PLASMIDMAP of: pPU203.Seq check: 5464 from: 1 to: 4838

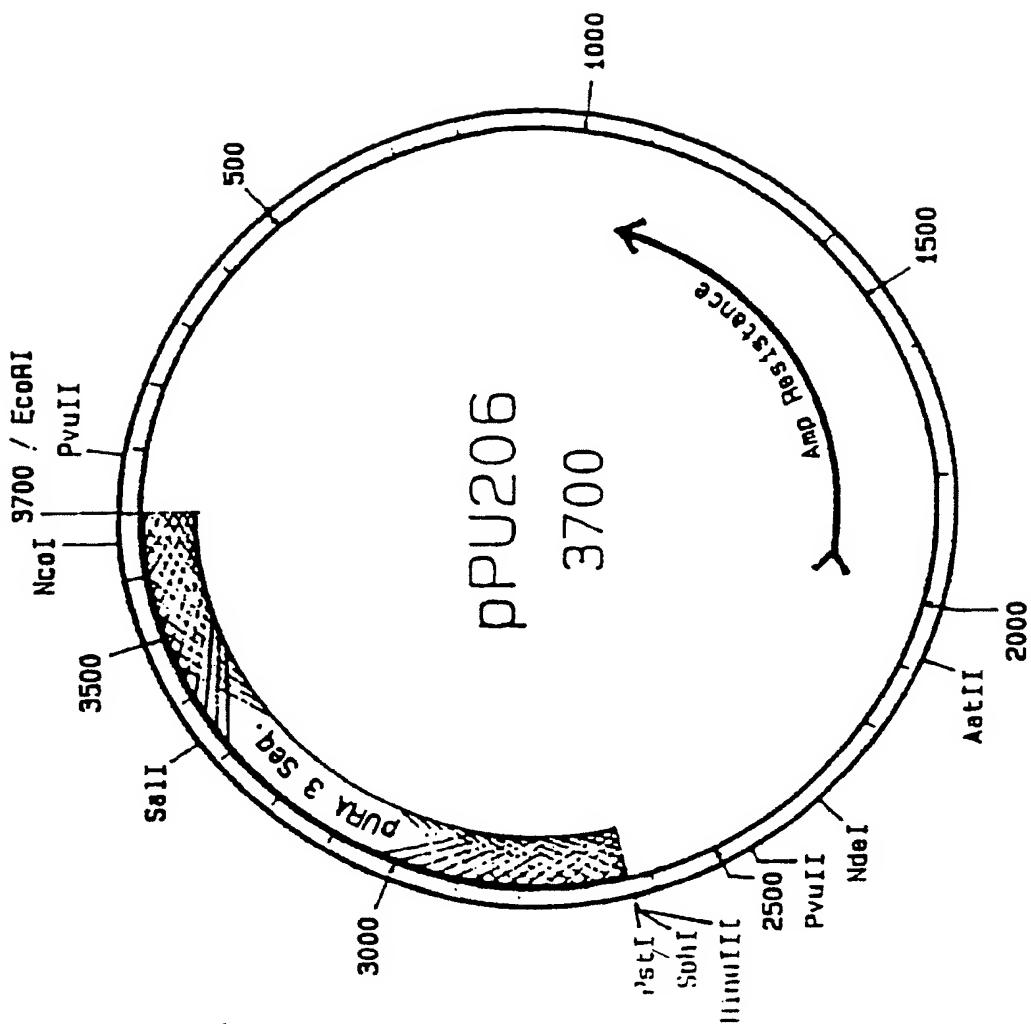
Howard April 4, 1990 10:19

FIG  
9

PLASMIDMAP of: pPU205.Seq check: 5464 from 1 to: 4855

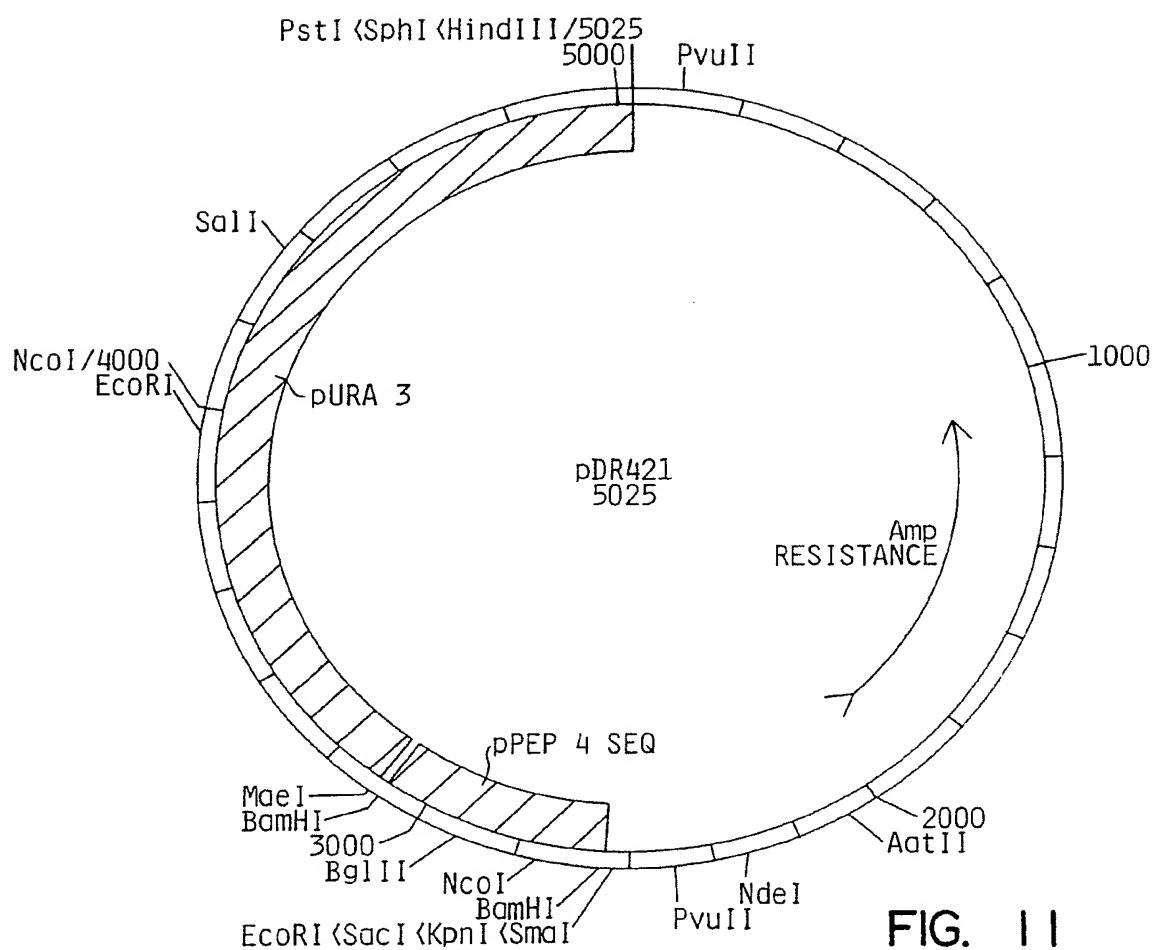
Howard April 4, 1990 10:33

FIG 10



PLASMIDMAP of: pPU206. Seq check: 5464 from: 1 to: 3700

Howard April 4, 1990 10:39



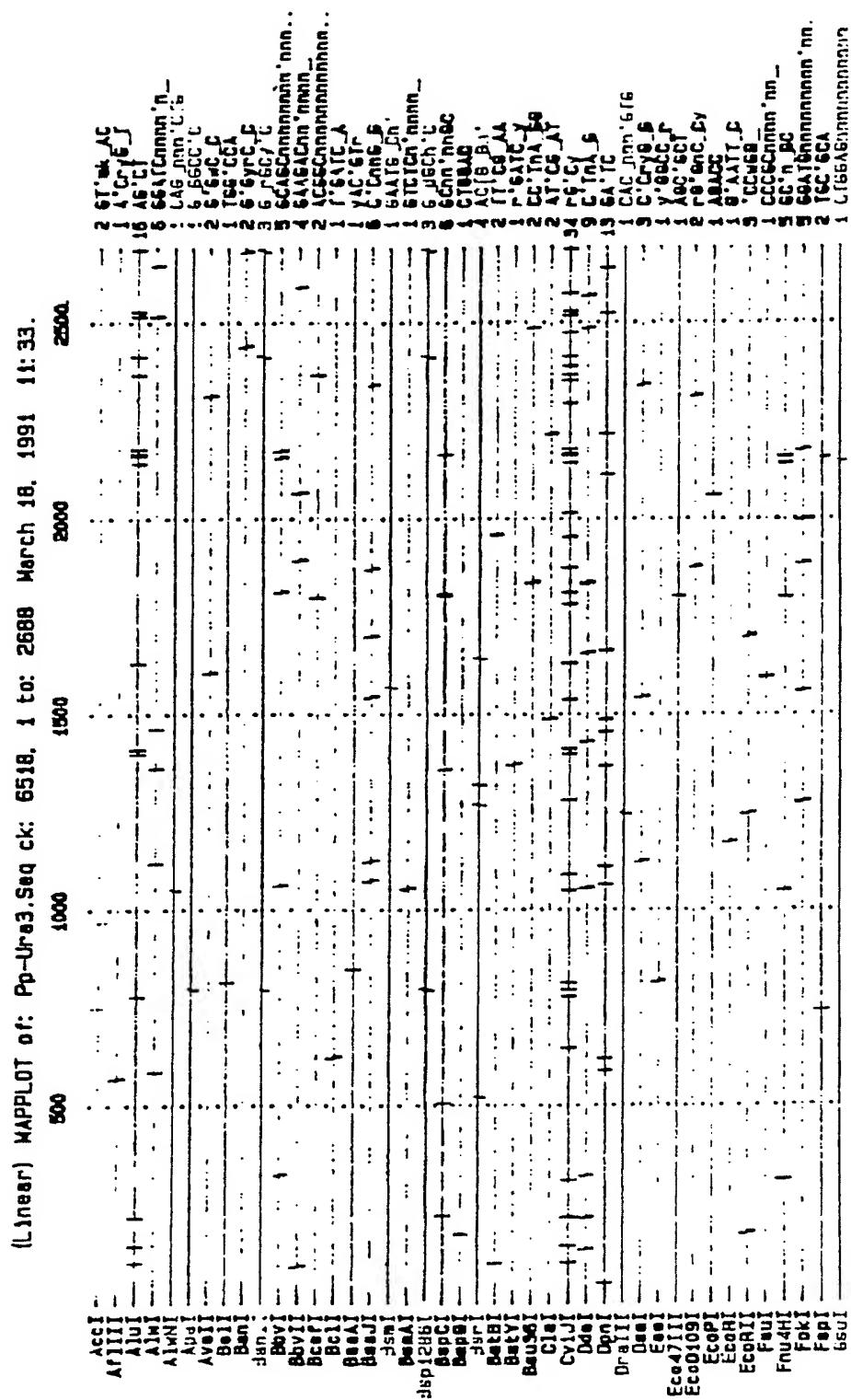


FIG. 12-1

15 / 23

(Linear) MAPPLT of: Pp-Ur3.Seq ck: 6518, 1 to: 2688 March 18, 1991 11:34.

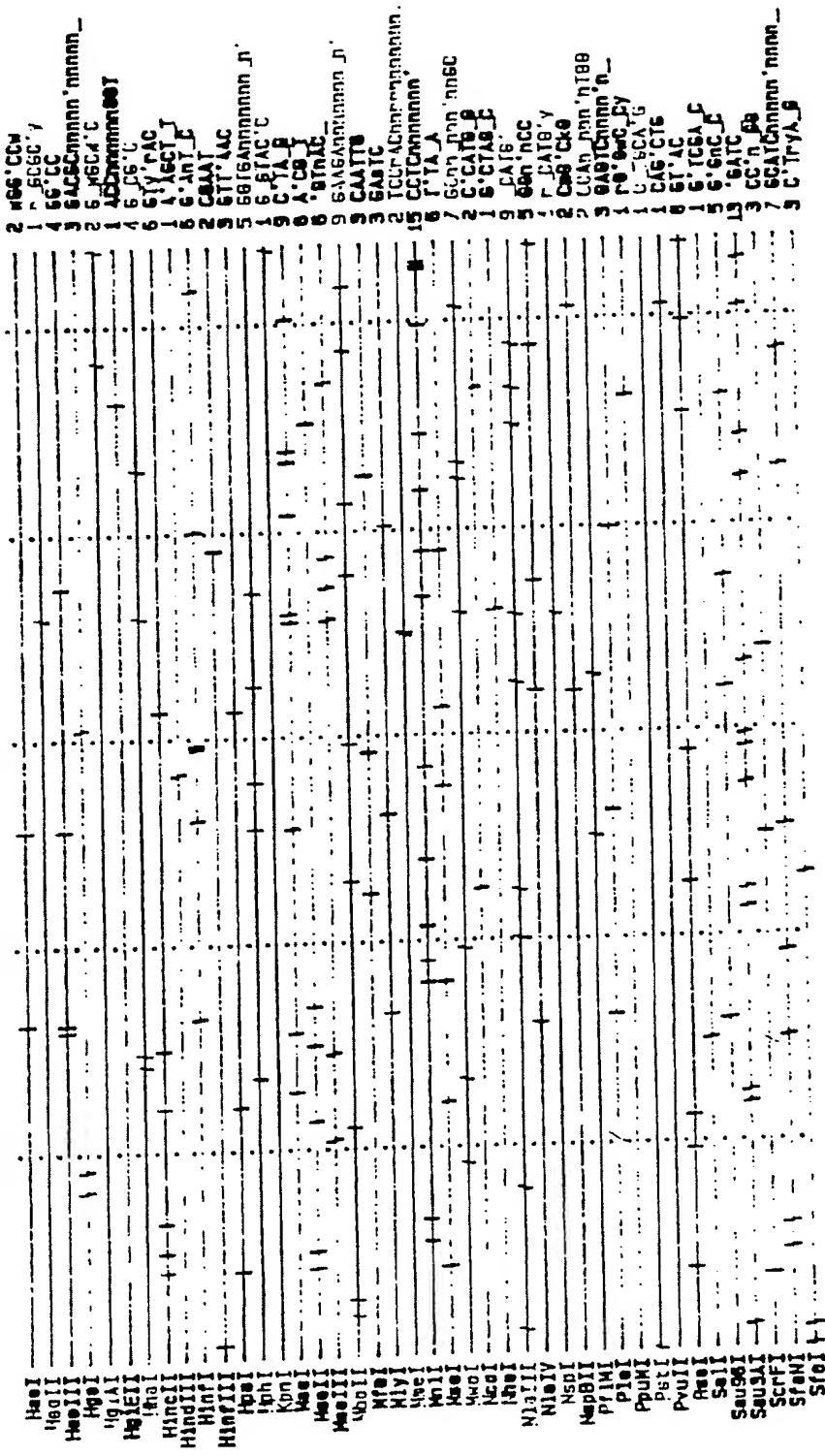
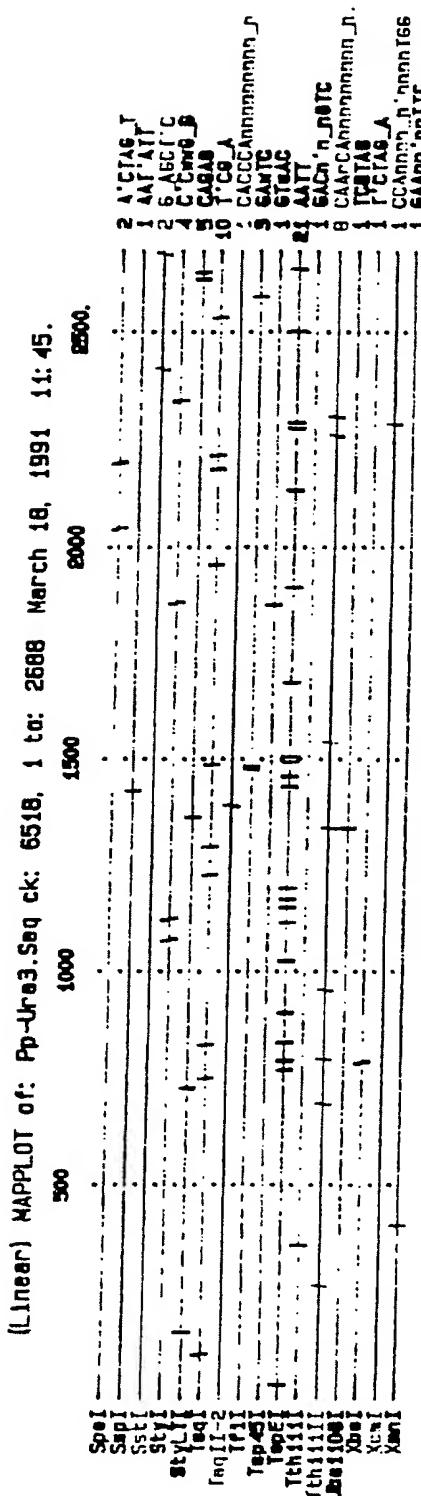


Fig.

12-2



Ensures that do not cut:

FIG.

12-3

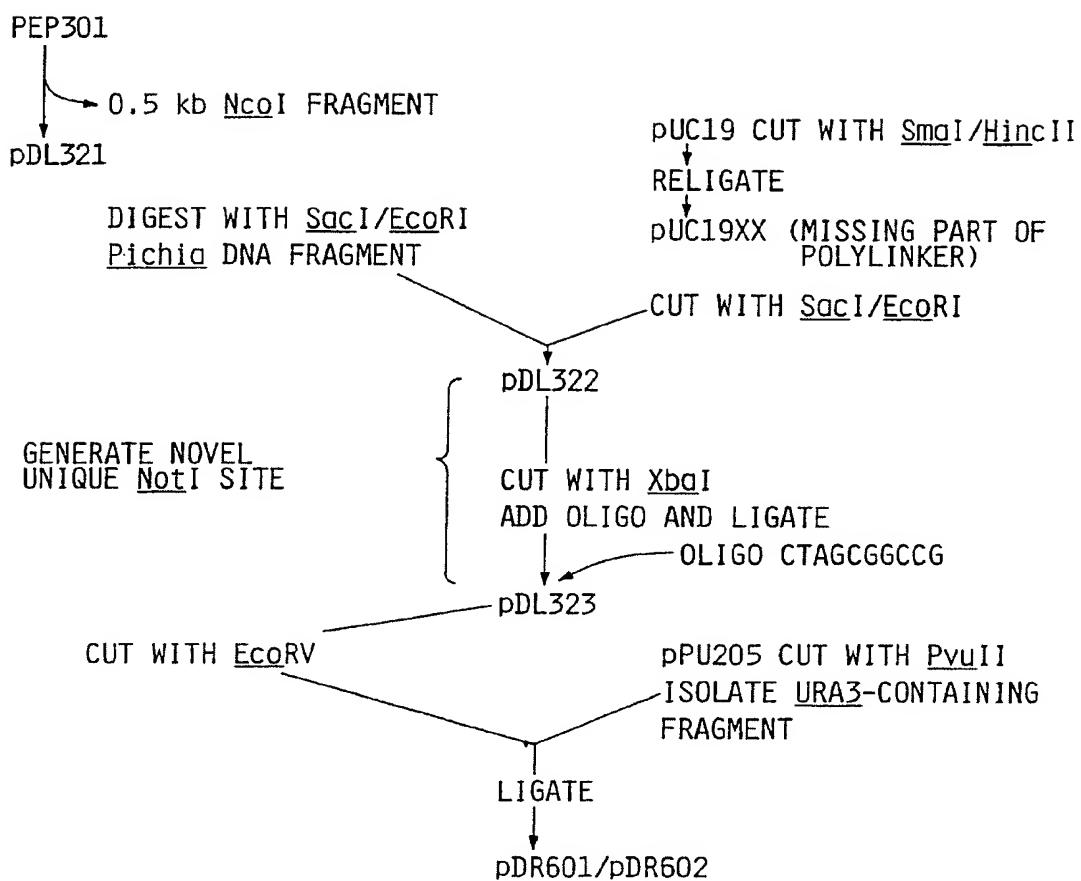


FIG. 13

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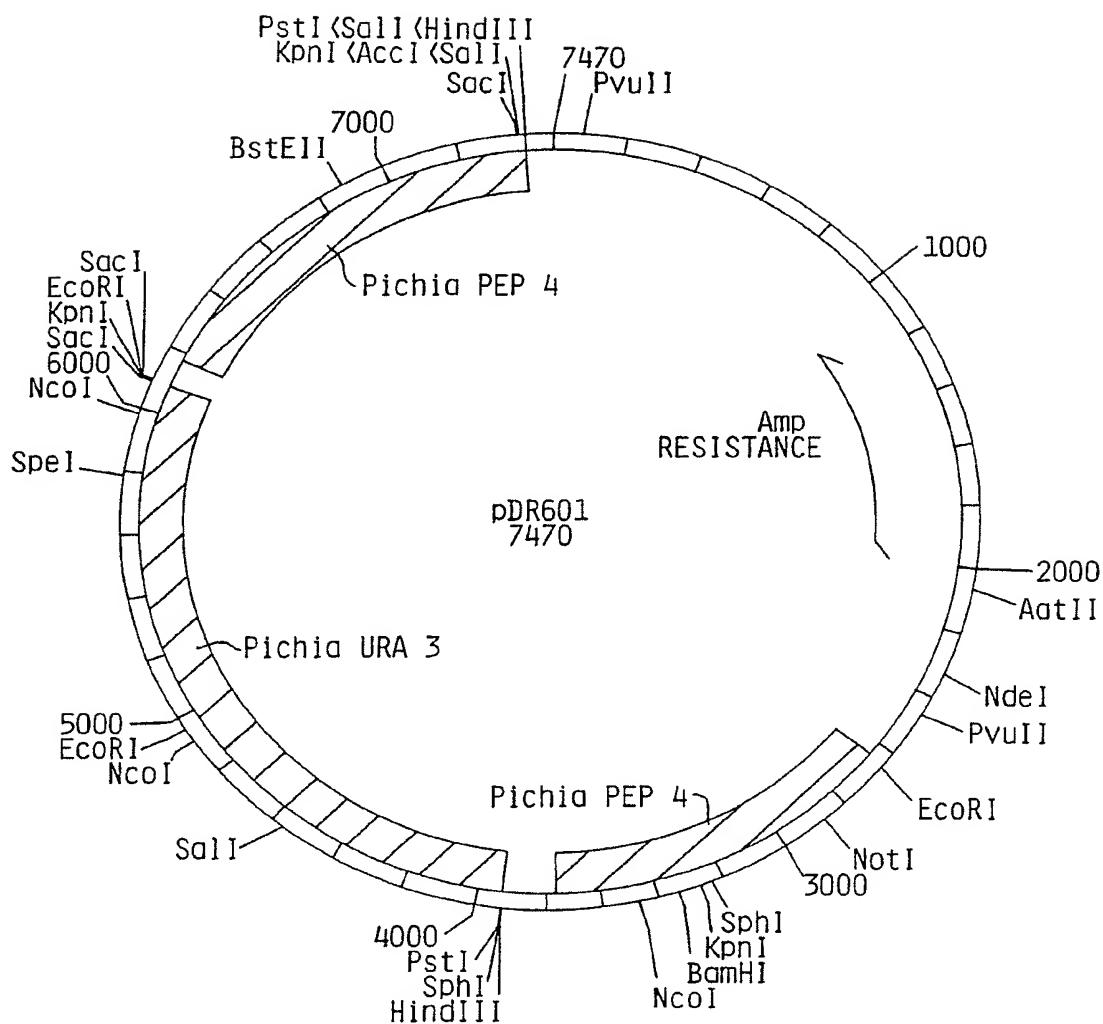


FIG. 14

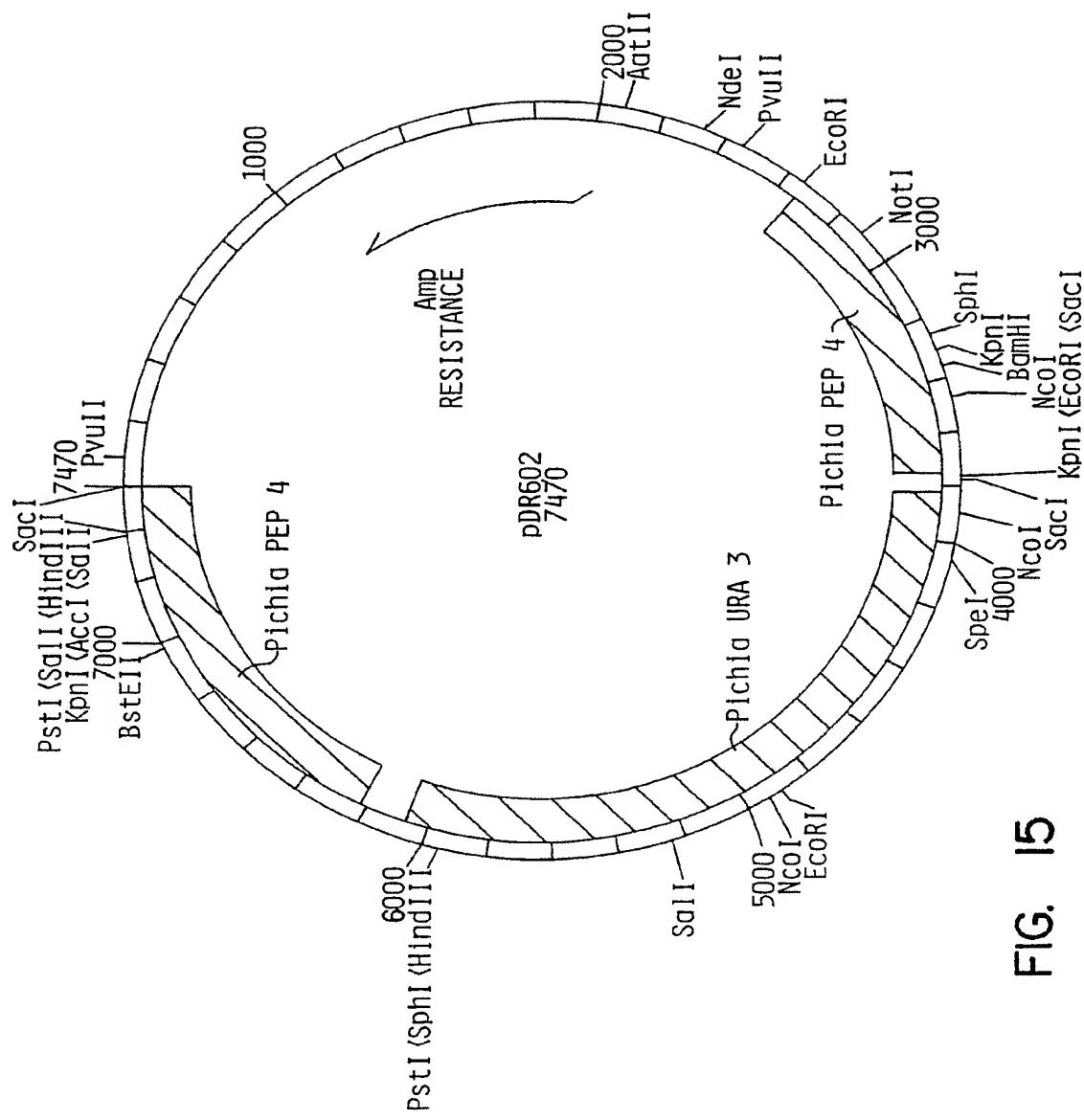


FIG. 15

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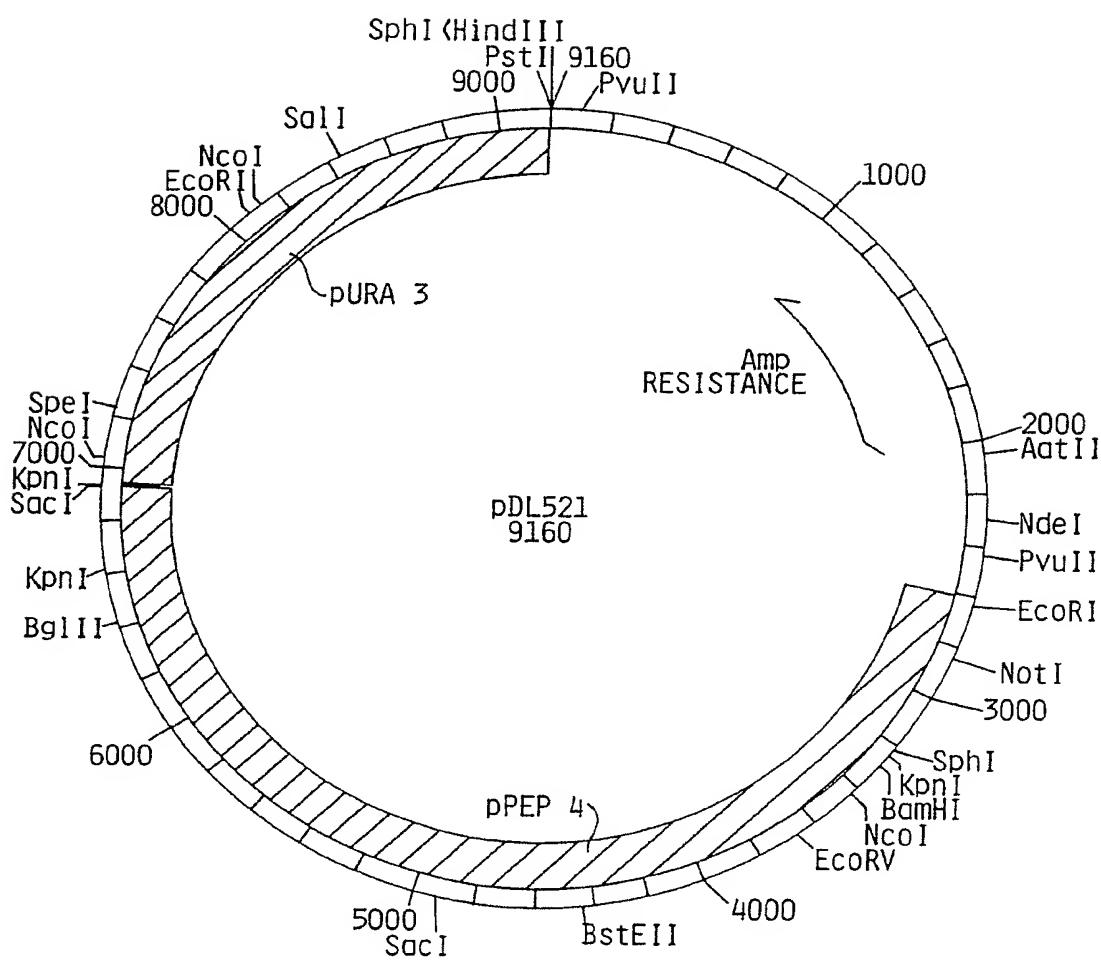
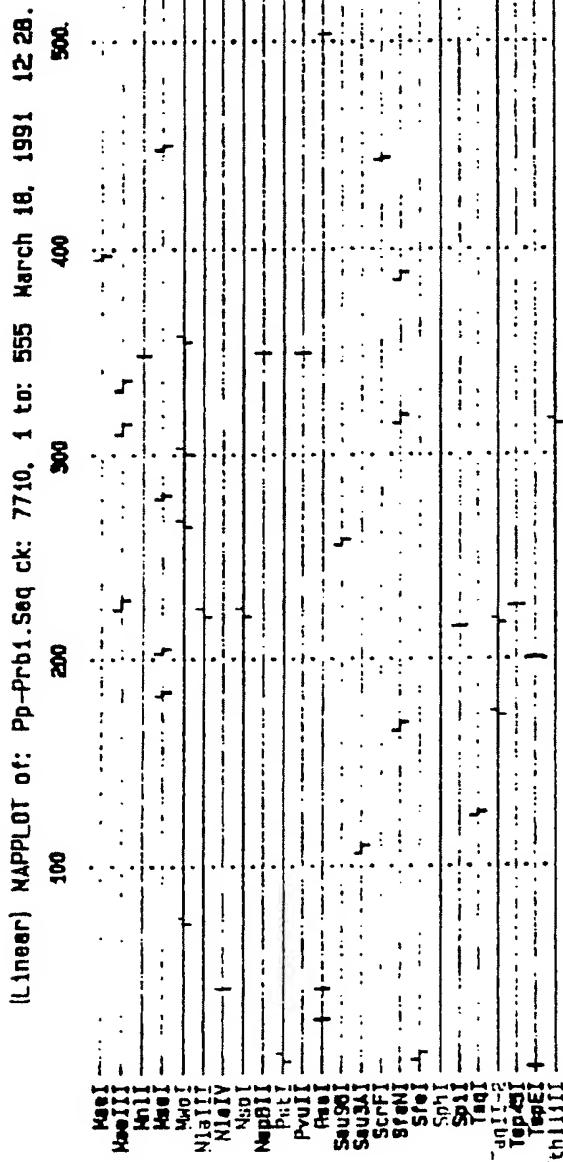


FIG. 16

[L1near] MAPPLT of: Pp-Prb1.Seq ck: 7710, 1 to: 555 March 18, 1991 12:28.

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enzymes that do not cut

17-2

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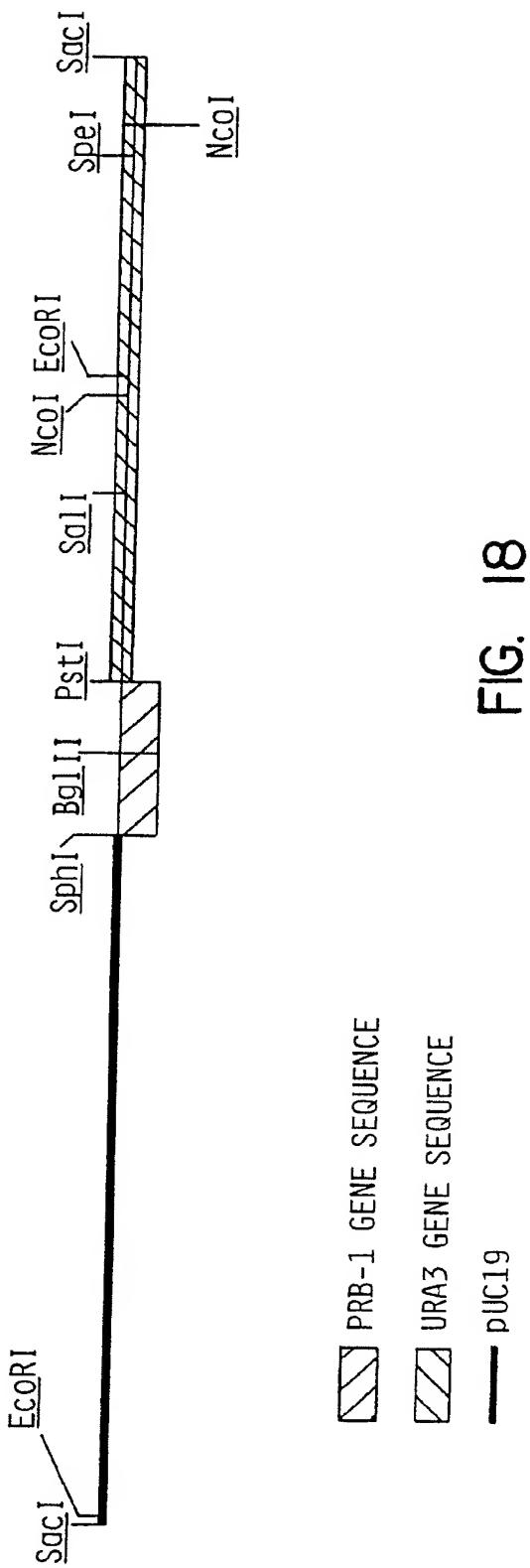


FIG. 18

SUBSTITUTE SHEET

## INTERNATIONAL SEARCH REPORT

International Application No.

PCT/US 92/02521

I. CLASSIFICATION OF SUBJECT MATTER (If several classification symbols apply, indicate all) <sup>6</sup>		
According to International Patent Classification (IPC) or to both National Classification and IPC		
Int.C1. 5 C12N15/81; C12N1/19;	C12N15/57; C07K13/00	C12N15/53; C12N15/60
II. FIELDS SEARCHED		
Minimum Documentation Searched <sup>7</sup>		
Classification System	Classification Symbols	
Int.C1. 5	C12N	
Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched <sup>8</sup>		
III. DOCUMENTS CONSIDERED TO BE RELEVANT <sup>9</sup>		
Category <sup>10</sup>	Citation of Document, <sup>11</sup> with indication, where appropriate, of the relevant passages <sup>12</sup>	Relevant to Claim No. <sup>13</sup>
A	EP,A,0 336 056 (M & D RESEARCH CO) 11 October 1989 see page 1, last paragraph - page 2; claim 2 ----	1
A	CHEMICAL ABSTRACTS, vol. 106, 1987, Columbus, Ohio, US; abstract no. 48594, G. NELSON AND T. YOUNG: 'Yeast extracellular proteolytic enzymes for chill-proofing beer' page 505 ;column L ; see abstract & J. INST. BREW. vol. 96, no. 6, 1986, pages 599 - 603; ----	1
		-/-
<p><sup>10</sup> Special categories of cited documents :      "A" document defining the general state of the art which is not considered to be of particular relevance      "E" earlier document but published on or after the international filing date      "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)      "O" document referring to an oral disclosure, use, exhibition or other means      "P" document published prior to the international filing date but later than the priority date claimed</p> <p><sup>11</sup> "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention      "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step      "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art      "&amp;" document member of the same patent family</p>		
IV. CERTIFICATION		
Date of the Actual Completion of the International Search 11 AUGUST 1992	Date of Mailing of this International Search Report 20.08.92	
International Searching Authority EUROPEAN PATENT OFFICE	Signature of Authorized Officer VAN DER SCHAAL C.A.	

III. DOCUMENTS CONSIDERED TO BE RELEVANT		(CONTINUED FROM THE SECOND SHEET)
Category	Citation of Document, with indication, where appropriate, of the relevant passages	Relevant to Claim No.
A	EP,A,0 390 676 (TRANSGENE S.A.) 3 October 1990  see the whole document ----	8, 9, 11, 12, 14, 16, 17, 19, 22, 23, 26, 28-30
A	BIOTECHNOLOGY vol. 7, no. 2, February 1989, NEW YORK US pages 160 - 164; M. DIGAN ET AL: 'Continuous production of a novel lysozyme via secretion from the yeast, Pichia pastoris' see the whole document ----	32
A	WO,A,9 009 449 (HENKEL RESEARCH CORPORATION) 23 August 1990  see abstract; claims ----	22, 31, 32, 34, 39-48
A	GENE. vol. 29, 1984, AMSTERDAM NL pages 113 - 124; M. ROSE: 'Structure and function of the yeast URA3 gene: expression in Escherichia coli' see the whole document ----	39
A	MOLECULAR AND CELLULAR BIOLOGY vol. 6, no. 7, July 1986, WASHINGTON, US pages 2490 - 2499; G. AMMERER ET AL: 'PEP4 gene of <i>Saccharomyces</i> <i>cerevisiae</i> encodes Proteinase A, a vacuolar enzyme required for processing of vacuolar precursors' see abstract; figure 2  ----	2, 5, 10, 18, 20, 24, 29, 31, 36, 47

ANNEX TO THE INTERNATIONAL SEARCH REPORT  
ON INTERNATIONAL PATENT APPLICATION NO. US 9202521  
SA 59408

This annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report. The members are as contained in the European Patent Office EDP file on The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information. 11/08/92

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EP-A-0390676	03-10-90	FR-A-	2645175	05-10-90
		CA-A-	2013240	30-09-90
		JP-A-	3072868	28-03-91
WO-A-9009449	23-08-90	EP-A-	0457852	27-11-91